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Changing Vegetation Patterns in Big Marsh and Other Bay of
Quinte Coastal Wetlands: 1929 to 1993. M.A. Thesis.

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University of Toronto. Dept. of Geography.



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COASTAL WETLANDS: 1929 TO 1993**

by

Andrew Timothy Watson

Earth Sciences Library

A research paper submitted in conformity with the requirements
for the degree of Master of Arts
Graduate department of Geography
University of Toronto

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ABSTRACT

This study analyses changes that occurred in vegetation community patterns within Big Marsh and five other Bay of Quinte coastal wetlands between 1929 and 1993. It identifies changes in the importance and distribution of marsh, shrub swamp, and tree swamp from vertical aerial photographs that were taken between 1929 and 1993. Over this time, there has been a loss of marsh communities to shrub swamp and tree swamp, as well as to reclamation. The amount of open water, shrub swamp, and tree swamp has increased within most of the wetlands. The changes reflect responses to a combination of natural and anthropogenic influences.

Major biological factors have probably been cattle intrusion and the invasion of Typha angustifolia. Cattle has destroyed wetland vegetation through grazing and trampling, and Typha angustifolia has out competed many of the plants native to these wetlands prior to European settlement. The most significant influence is likely to have been changes in hydrology. Although there has been a reduction in Lake Ontario fluctuations over the last 20 years, this change has not had any noticeable impact upon vegetation communities. However, a 20 year period may be too short for vegetation communities to have responded. The causeway and dam constructed at Big Marsh are likely to have increased siltation, but their impacts were not identifiable through the methods used within this study. Increased nutrient inputs from the bay and from human activities in the watersheds may also have stimulated infilling of marsh communities with swamp communities.

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1 INTRODUCTION

There are 55 000 hectares of coastal wetlands on the Lower Great Lakes and St. Lawrence River, which makes up fifteen percent of all of the wetland habitats in Southern Ontario (Smith, 1988). However, 35% of the original wetlands on Lake Ontario have disappeared, and there has been a virtual elimination of coastal wetlands near major urban centres (The State of Canada's Environment, 1991). The remaining coastal wetlands are increasingly threatened with destruction or severe degradation.

Currently, only 7 000 hectares of wooded and emergent wetlands exist in the Bay of Quinte watershed. It has been estimated that 12 000 hectares of coastal wetlands in this region have been destroyed during this century (Bay of Quinte RAP, 1989). Bay of Quinte coastal wetlands are largely cattail dominated monocultures, and it is believed that they possessed a greater amount of vegetation diversity in the past (Hartly, 1994a).

Coastal wetlands along the Bay of Quinte are biologically important. They are significant migration points for waterfowl (Prince et al., 1992). These wetlands are also important fish habitat and promote diverse fish populations through reducing predation risk for larval and juvenile fish (Jude and Pappas, 1992).

The bay's wetlands are composed of marsh and swamp communities. Marshes are characterized by robust emergents, and to a lesser extent, anchored floating plants and submergents. The water within a marsh is usually slightly acidic and contains a relatively high dissolved oxygen content. These communities are often broken-up by channels or pools (MNR, 1993). Swamps are wooded wetlands located where surface water persists seasonally or over long periods. Substrates within swamps must be drier than those of marshes, because mature trees and seedlings require a greater amount of oxygen in the soil than emergents (Klimas, 1988). These waters are circumneutral to moderately acidic and there is little deficiency in oxygen or organic sediments (Gore, 1983). Shrub swamp communities are composed of lower woody plants that grow to a height of approximately six metres and tree swamps are taller than six metres.

Vegetation communities are indicators of complex conditions which are difficult to measure and interpret individually (Bellan, 1991). Kuchler and Zonneveld (1988) claim that the community taken as a unit reveals the nature of a site more accurately and comprehensively than any other method. Furthermore, most wildlife is adapted primarily to one or more plant forms; hence, vegetation communities are clear indicators of wildlife diversity (MNR, 1993).

Since vegetation communities grow within restricted environmental ranges, their presence indicates that these parameters have remained within the tolerance limits of the species that reside in stand within their lifespan (Hellawell, 1988).

Vegetation communities represent an aggregation of taxa capable of successfully

competing with each other within the confines of a particular combination of environmental features that they can tolerate (Kuchler and Zonneveld, 1988; Causton, 1988).

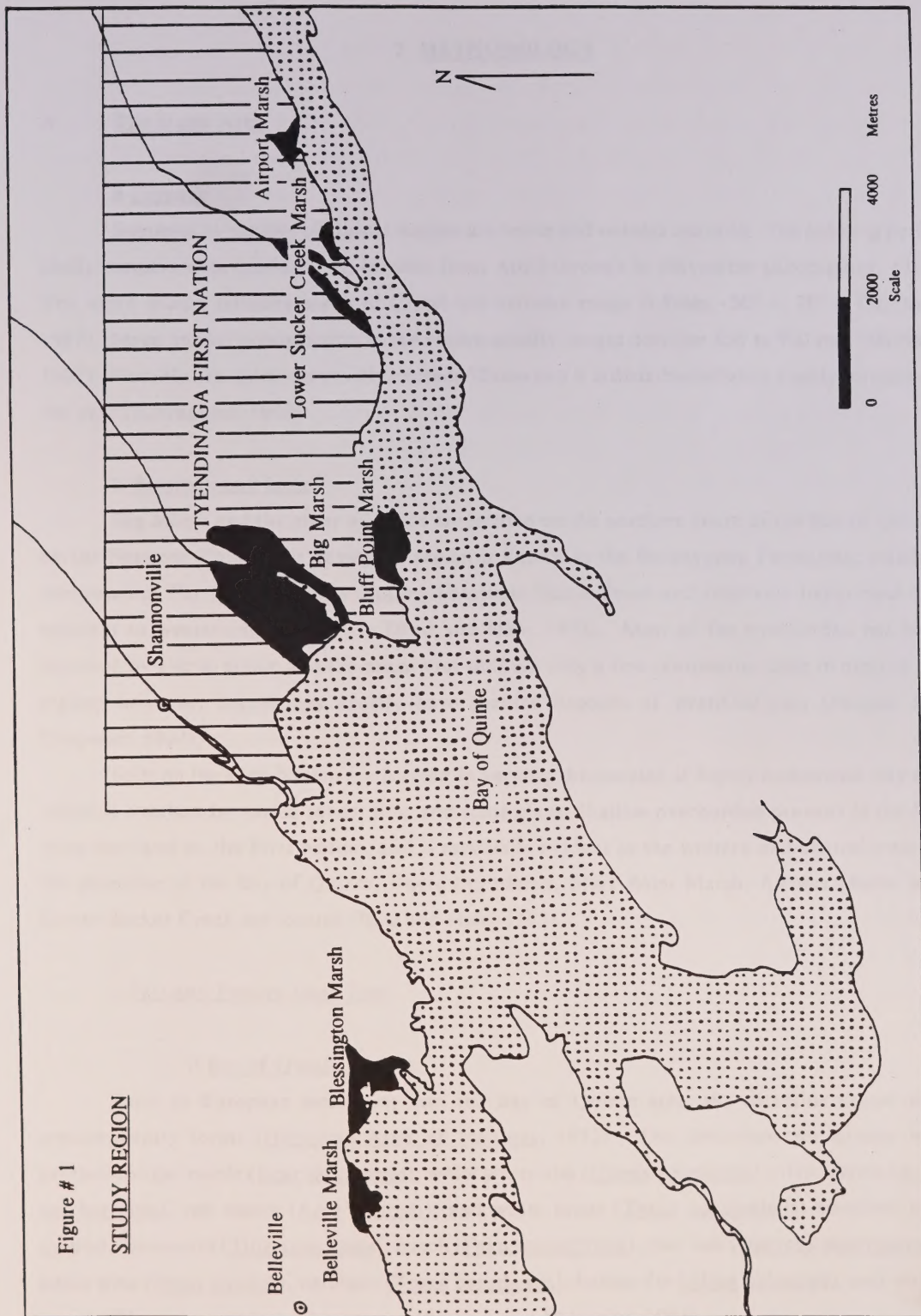
This paper analyses alterations that have occurred in the Bay of Quinte's wetlands vegetation communities since 1929, through identifying changes in major vegetation communities. Vegetation communities used in this study are : a) marsh stands; b) shrub swamps; and c) tall tree swamps. It is hypothesized that changes have taken place in vegetation communities through succession as well as the following external factors: a) changes in Bay of Quinte water levels; b) land use; c) modifications that have been made to the marsh; d) activities of native and exotic fauna; e) exotic plants; f) eutrophication; and g) siltation

It focuses on Big Marsh and five other coastal wetlands: Airport Marsh, Belleville Marsh, Blessington Marsh, Bluff Point Marsh, and Lower Sucker Creek Marsh (see figure # 1). Big Marsh is a riverine wetland, located at the mouth of Mud Creek, on the northern shore of the Bay of Quinte (see figure # 1). Mud Creek flows from the north-east to south-west, it drains an area of fifty-six square kilometres. Its drainage basin has a relief of less than seventeen metres (Conestoga Rovers, 1992). The 468 hectare marsh is sited on the Tyendinaga First Nation, and local residents are concerned about the future of the wetland. Several members of the community hunt and trap duck, beaver, muskrat, and otter in Big Marsh and others use it for recreational and aesthetic purposes. As a result, there is an interest in understanding changes that have occurred in the marsh, evaluating its current condition, and future perspectives.

Vertical aerial photographs taken between 1929 and 1993 have been used, along with historical maps, to identify changes that have occurred in vegetation communities found in Big Marsh and five other wetlands. Vegetation communities are often divided along environmental gradients (Mitsch and Gosselink, 1993); hence, their boundaries may be used as indicators of particular ecological parameters. Changes in community area will be used as indicators of wetland alterations that occurred between 1929 and 1993.

Vegetation form was the basic criterion used to identify the vegetation communities that existed within Big Marsh and the other marshes. Form is the appearance of a plant community, which is determined by its height, tone, and branching pattern (MNR, 1993; Kuchler and Zonneveld, 1988). Krebs (1994) claims that vegetation community growth forms reflect environmental conditions and similar milieu produce similar growth forms. Thus it is assumed that it was possible to compare vegetation communities changes that have occurred in different coastal wetlands located on the Bay of Quinte.

One useful property for this analysis of Bay of Quinte coastal wetlands is that marsh, shrub, tree communities are quite distinct of each other and open water. The borders between open water, marsh communities, and shrub communities are usually sharply edged. Narrow ecotones may exist between some of the shrub and tree communities; however, this does not create many difficulties for aerial photograph interpretation and fieldwork.



2 METHODOLOGY

A The Study Area

a Climate:

Summers in the Bay of Quinte Region are warm and winters are mild. The growing period (daily temperatures exceed 0° C) extends from April through to November (Ecoregions, 1989). The mean annual temperature is 6° C and the extreme range is from -36° to 38° C (Michael, 1987). Mean annual precipitation in the region usually ranges between 850 to 900 mm (Michael, 1987). Monthly precipitation usually exceeds 70 mm and it is distributed fairly evenly throughout the year (Ecoregions, 1989).

b Baserock and Soils:

Big Marsh and the other wetlands are located on the northern shore of the Bay of Quinte, on the Napanee Plain. This geological region is known as the Bobcaygeon Formation, which is composed of flat lying to gently dipping limestone that is dense and relatively impervious and resistant to weathering by solution (Bird and Hale, 1973). Most of the overburden has been removed by glacial action and the calcareous soils are only a few centimetres deep in most of the region; however, depressions usually have shallow deposits of stratified clay (Putnam and Chapman, 1984).

Soils on the First Nation are formed in varying thicknesses of highly compacted clay till, which is overlain by varied sands, silts, and some clays. Shallow overburden prevails in the flat lying low land on the First Nation, and is especially evident in the western and central areas of the shoreline of the Bay of Quinte, where Big Marsh, Bluff Point Marsh, Airport Marsh, and Lower Sucker Creek are located (Bird and Hale, 1973).

c Past and Present Land Use:

i) Bay of Quinte Region:

Prior to European settlement into the Bay of Quinte area, the shoreline region was predominantly forest (Historical Atlas of Hastings, 1972). The dominant tree species was probably sugar maple (Acer saccharum), while white elm (Ulmus americana), silver maple (Acer saccharinum), red maple (Acer rubrum), and white cedar (Thuja occidentalis) occupied low ground. Basswood (Tilia americana), beach (Fagus grandifolia), bur oak (Quercus macrocarpa), white pine (Pinus strobus), hemlock (Tsuga canadensis), balsam fir (Abies balsamea), and white spruce (Picea glauca) were also present (Putnam and Chapman, 1984).

There were few aboriginal settlements in the Bay of Quinte region prior to European settlement. Anthropogenic disturbances appear to have been limited to Prince Edward County and Lower Napanee River (Sly, 1986). Once colonists began to settle this region after 1820, their impact on the region was quick and severe. By 1835, the land along the Bay of Quinte front townships had been virtually cleared. Logging continued throughout the 1800s; however, by the early 1900s, the forests of the Bay of Quinte watershed had been depleted and logging ceased (Bay of Quinte RAP, 1989).

Agriculture in the area shifted from subsistence to commercial agriculture by 1830. While 2 000 people inhabited the Bay of Quinte drainage basin in the 1790s, this number increased to 90 000 by the beginning of the nineteenth century, and 230 000 by 1886 (Sly, 1986).

Another influential historical factor was the construction of a railway line along the northern shoreline of the bay in the 1890s. This branch was abandoned between 1917 and 1922 (Rae, 1994). Remnant causeways from this line currently affect water flow in Big Marsh and Blessington Marsh, and sections of the railway bed remain north of Belleville Marsh and Bluff Point Marsh. The construction of the four lane Highway 401 and the older two lane Highway 2 also affected the quality of water entering the rivers that feed most of the marshes involved in this study and land uses in this region.

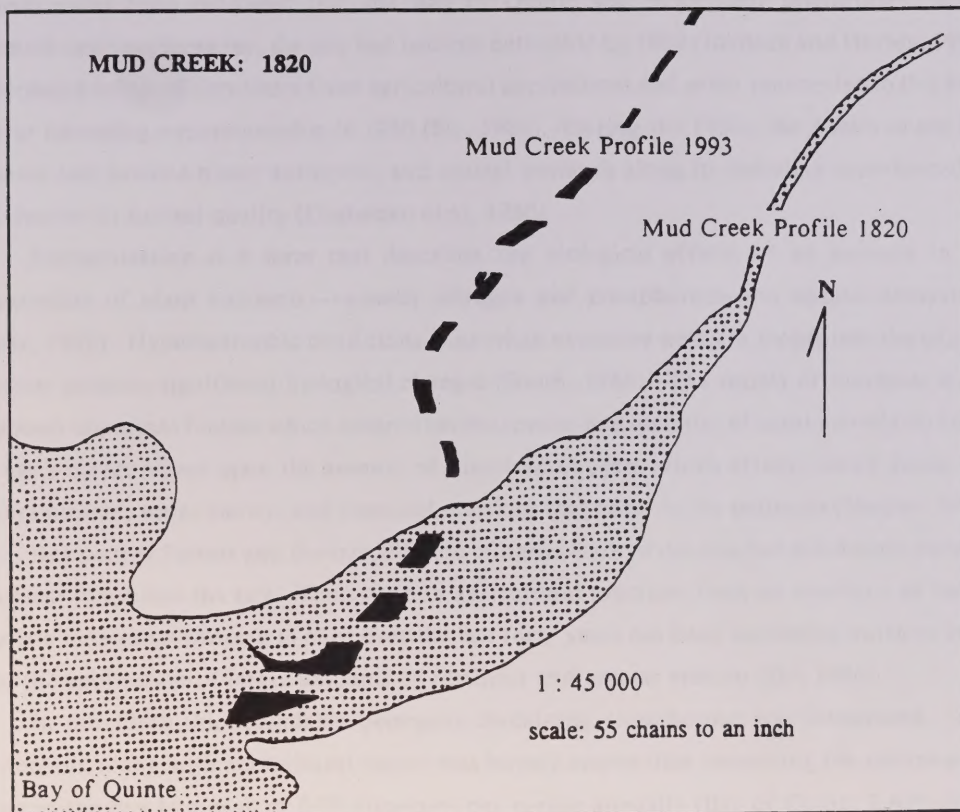
ii) Tyendinaga First Nation:

Mohawk settlement of the Tyendinaga First Nation began in 1804, and by 1820, the area was being cleared for agriculture and roads had been constructed (Illustrated History, 1972). Boyce (1967) estimated that by 1830, 142 hectares of the township was being cultivated (1967). The appearance of Big Marsh shortly after the Bay of Quinte drainage basin was cleared is presented on figure # 2. Prior to anthropogenic impacts, Big Marsh was much wider and an open bay along the Bay of Quinte has been filled in since. Population on the First Nation peaked at over 7 000 in the late 1860s; however this declined to 4 000 by 1900 and 2 000 by the 1940s. Boyce (1967) attributes this population decline to the depreciation of the lumber industry and the abandonment of marginal and submarginal lands. In 1992, the Tyendinaga First Nation covered an area of 7 274 hectares and the population was 1 831 (ONAS, 1992).

During the Great Depression, virtually all of the arable land on the First Nation was being cultivated (Boyce, 1967). However, since then agriculture has decreased. Recent farm practices are described in the following section that focuses on current land uses.

A 200 metre long causeway was built along the mouth of Big Marsh for the Grand Trunk Railway in the 1890s and this has been used by Beach Front Road since the railway line was abandoned after 1917. A dam was constructed adjacent to the causeway in 1962 to regulate water levels in an attempt to attract water fowl. This dam has been used occasionally, although there has not been an organized pattern to its operation.

Figure # 2



Source: Sherwood, R., "Mohawk Lands." Ottawa: Department of Lands and Forests, 1820.

iii) Changes in the Bay of Quinte:

Historically, the Bay of Quinte was the most productive fishery on Lake Ontario. Sediment cores have indicated that the Bay of Quinte was moderately oligotrophic in the nineteenth century; however, the bay had become eutrophic by 1980 (Johnson and Hurley, 1986). An increased influx of fertilizers from agricultural applications and other sources led to this body of water becoming hypereutrophic in 1950 (Sly, 1986). During the 1960s, the waters in the Bay of Quinte had become hyper eutrophic, and coastal wetlands along its shoreline experienced a rapid decline in habitat quality (Dushenko et al, 1980).

Eutrophication is a term that describes the biological effects of an increase in the concentration of plant nutrients---usually nitrogen and phosphorous---on aquatic ecosystems (Harper, 1992). Hypereutrophic conditions exist when excessive nutrient inputs into the aquatic ecosystem produce significant biological changes (Smith, 1986). The supply of nutrients is one of the most important factors which determines the species and quantity of plant material in lakes. This has a direct effect upon the amount of dissolved oxygen, which effects which fauna and flora are present, water clarity, and chemical reactions that occur in the sediment (Harper, 1992).

Removal of forests and the introduction of agriculture to the area led to a drastic increase of nutrient input into the bay. The switch in agricultural practices from an emphasis on barley in the late nineteenth century to corn over the last forty years has been increasing nutrient input due to the application of larger amounts of fertilizer and greater erosion (Sly, 1986).

In the 1960s, biodegradable detergent containing phosphorous was introduced. This introduction, along with agricultural inputs was largely responsible increasing the phosphorous loading in the Bay to a peak of 0.73 kilograms per person annually (Bay of Quinte RAP, 1993).

In an attempt to limit the amount of nutrients that entered the bay from point sources, sewage treatment using primary treatment plants were constructed at Picton and Prince Edward Heights during the 1940s; Napanee, Canadian Forces Base Trenton, and Trenton during the 1950s; at Belleville during the 1960s; and at Deseronto during the 1970s. Primary treatment separates suspended solids from waste water through sedimentation, prior to release of the water into the bay. Secondary treatment was added to Picton, Trenton, and Belleville in 1978. Secondary treatment removes dissolved and suspended nutrients from the effluent of primary treatment with aerobic bacteria.

Nevertheless, nutrient inputs from point sources continue. The effects of phosphorous on coastal wetlands will be considered in Chapter 4.

Several hydrological changes have occurred in the bay due to the construction of several structures. Completion of the Trent Canal System in 1830 changed the natural flow regime by reducing water exchange in the spring and increasing it during the summer (Bay of Quinte RAP, 1993). A series of dams were built at Cornwall, Ontario in 1960 to control Lake Ontario water levels, and this project succeeded in regulating water levels by 1973 (Ecological Services for

Planning, 1992). It is important to note that these dams have not altered the minimum and maximum ranges of these fluctuations; however, the mean annual values have decreased in the last twenty years. This aspect will be discussed in Chapter 4.

d Current Land Use:

Currently, much of the marginal land has been abandoned. White cedar and shrubs have invaded much of the vacant farmland (Putnam and Chapman, 1984), and woodlots are forming. About sixty percent of the land area draining into the bay is forested and thirty-seven percent is agricultural (Michael, 1987).

Much of the traditional cattle grazing on the First Nation has ceased and forest cover is beginning to return (Green and Hill, 1992). Present farm practices on the First Nation are fairly conservative, and most farmland is dedicated to pasture and a few row crops (Crowder, 1993). Mud Creek has two kilometres of shoreline that is used for grazing by approximately one hundred and sixty head of cattle, and the tributaries for Lower Sucker Creek Marsh are grazed by approximately one hundred head of cattle (Graham, 1993). The source of Mud Creek lies off of the First Nation, and this land is intensively farmed. The major crop north of the First Nation is hay, although a limited amount of row crops are grown (Reily, 1993).

B The Study Sites:

Big Marsh was selected as the focus of the study, because of its importance to the Tyendinaga Community and because little research has been conducted on it. Construction of the causeway and dam across the mouth of this 468 hectare wetland may have altered its vegetation patterns during this study period. Furthermore, land uses on the First Nation are different than the surrounding area, and it will be interesting to identify if this factor has affected Big Marsh.

To determine if the changes in Big Marsh are representative of coastal wetlands in the Bay of Quinte area, several other wetlands were investigated. The latter were selected because of the similarity of their physical settings. All have been recently evaluated by the Ontario Wetland Evaluation System. Factors taken into account during this selection process included the following attributes: a) soil types; b) base rock; c) exposure to the Bay of Quinte; d) it required an area that was small enough to be worked with; e) adjacent land uses and f) topography. Coastal marshes on Prince Edward County were not considered because the shoreline along the Bay of Quinte consists of steep hills, while the north shoreline of the bay is a relatively flat. Prince Edward County Coastal marshes have their mouths facing north, which may subject them to different hydrological conditions than the wetlands on the north shore.

A review of coastal marshes on the northern shore of the Bay of Quinte eliminated Salmon Creek Marsh and Haybay Marsh. Haybay Marsh was considered too large to be encompassed in this study. The Salmon River is located along a fault line (Carson, 1981), which

probably presents this river with different hydrologic properties than Mud Creek. Since Salmon Marsh reaches out into the Bay of Quinte, it was eliminated because it was exposed to wave action, which makes it Quite different than the sheltered Big Marsh.

The following coastal wetlands were used in this study: a) Airport Creek Marsh; b) Belleville Marsh; c) Blessington Point Marsh; d) Bluff Point Marsh; and e) Lower Sucker Creek Marsh. All of these marshes are located within twelve kilometres of Big Marsh. Belleville Marsh and Blessington Marsh are sited west of Big Marsh. These wetlands were selected because they represent Bay of Quinte coastal wetlands that are affected by land uses that are different than those found on the Tyendinaga First Nation. They are impacted by urbanization and more intensive agriculture. Airport Marsh, Bluff Point Marsh, and Lower Sucker Creek Marsh lie to the east. Bluff Point Marsh, Airport Marsh, and Lower Sucker Marsh are located on the Tyendinaga First Nation (see map titled "Big Marsh Study Area" Figure # 1); hence, they experiences similar land-use impacts at Big Marsh.

C Vegetation Analysis:

Field work formed the initial stage of this study. The first step involved the identification of major vegetation communities from the 1993 air photographs. It was at this stage that marsh, shrub swamps, and tall tree swamps were selected as the basic communities included in this study. A vegetation map created by Conestoga Rovers (1992) was used to assist with this process; however, the final vegetation communities were delineated from photographic interpretation. Once the stands had been delineated, a preliminary visit was made to examples of marsh, shrub, and tall tree community and samples of every type of vegetation found was identified. An estimate was also made of the frequency of each species. Hence, this allowed more common species to be used as indicator species that help identify the range of the communities.

After creating a check list, a systematic identification of vegetation species found in each of the communities was conducted to create a vegetation inventory for Big Marsh. The process involved a site visit, where each species observed in the community being studied was listed. Immediately after listing the plant species found in each community, each species was categorized into one of the following qualitative groupings: Dominant, common, uncommon, and rare. These categories were based upon the amount of area encompassed by each species present. The definition for dominant species was based upon the Ministry of Natural Resources categorization, which states that the species must be present in approximately 25% of the community before it is recognized as a dominant species (MNR, 1993). Common species were not present in 25 % of the community; nevertheless, they were spread fairly evenly throughout most of the community. The following chart identifies the dominant and common species identified within each of the major communities within Big Marsh:

Table # 1: Dominant and Common Species Found in the Major Communities of
Big Marsh

Marsh	Shrub Swamp	Tree Swamp
<u>Hydrocharis morsus-ranae</u> <u>Typha angustifolia</u> <u>Impatiens pallida</u> <u>Solanum dulcamara</u> <u>Asclepias incarnata</u> <u>Salix nigra</u> <u>Bidens frondosa</u> <u>Galium boreale</u>	<u>Salix amygdaloides</u> <u>Salix nigra</u> <u>Salix petiolaris</u> <u>Spiraea latifolia</u>	<u>Salix nigra</u> <u>Salix babylonica</u> <u>Salix amygdaloides</u> <u>Fraxinus nigra</u> <u>Spiraea latifolia</u> <u>Acer rubrum</u>

Properties of these dominant and common species were used as indicators of the major communities. The focus of the research on dominant and common vegetation has been on vulnerability to waterlogged soil. Virtually all of the major vegetation species in Big Marsh and the other wetlands can tolerate short term waterlogging. Major species found in each of the study wetlands is shown in appendix # 1.

Data collected was mostly qualitative in part to save time and because the 1993-1994 wetland evaluations of the other marshes had similar information. Also, little quantitative data could be obtained from historic photographs.

D Air Photograph Interpretation:

Vertical aerial photographs taken in 1929, 1962, 1978, and 1993 were used to study changes that occurred in Big Marsh vegetation communities. The 1929 aerial photographs of the other marshes were used in conjunction with 1993 wetland evaluations to study community changes in these coastal marshes. The basic communities used for this study are: a) marshes; b) shrub swamps; and c) tall tree swamps. The distinction of the shrub and tall tree swamp communities was based upon the format used by the Ontario Wetland Evaluation System, which classified tall trees as woody species that stand above six metres in height, and shrubs cover the range from ground level to six metres (MNR, 1993). Marshes are composed of emergent vegetation that has a profile that usually remains below two metres.

Open water, marsh, shrub swamp, and tall tree swamp communities were identified by their tones, textures, and through the use of a stereoscope. Tone refers to the relative brightness or colour of objects in the images. Texture is a term given to patterns of tonal change that can be used to determine different vegetation communities through overall "smoothness" or "coarseness" (Lilesand and Kiefer, 1987). Stereoscopes use parallax to interpret slightly differing views from two overlapping aerial photographs to present a three dimensional image, that was used to separate the four major types of communities that were used in this study.

The major advantage of using aerial photographs to study vegetation communities is that

instrumentation and techniques are relatively simple and techniques are well tested. Unfortunately, using air photographs to study historical vegetation community changes has three disadvantages that had to be dealt with: a) varying quality within different photographs; b) variable scales; and c) seasonal variations of aerial photographs.

Varying quality between the different photographs proved to be the greatest difficulty of addressing. All of the air photographs were taken at a quality that allowed stereoscopes to be used to separate different communities, except for the 1929 examples. In this case, tone had to be relied upon, since the images did not present texture very well.

Aerial photographs used were taken at the following scales: 1929 was 1 : 6 570 ; 1962 was 1 : 5 982 ; 1978 was 1 : 10 000; and 1993 was 1 : 9 777. Roads and railways that appeared on the Ontario Base Maps and the aerial photograph being analyzed were used to calculate the average scale. The following formula was used to calculate the average scales for the different historic aerial photographs:

$$\text{scale} = \frac{\text{distance on the base map}}{\text{distance on aerial photograph}} / 10\,000$$

This value became the second portion of the ratio scale that calculated. For each set of air photographs used, three different measurements were made, (preferably from different images) and the average of the three was taken. Difficulties created by using images taken at different scales as well as parallax is discussed in greater detail in the following section.

Seasonal variation was not a major problem. Emergents tend to grow quickly in the spring to reach their maximum height and they remain little changed throughout the growing season (Moss, 1980), while shrub and tree communities are recognizable in photographs taken at any time of the year. Open water boundaries for the wetlands were drawn at the point where emergent vegetation ends and open water begins. Emergent plants are erect, rooted herbaceous flora, which may grow where their base is temporarily or permanently flooded, but their upper portions are almost always exposed (MNR, 1993). Since most of the marshes were surrounded by cleared land, the boundary was delineated at the point where anthropogenic action had removed the native vegetation. This was based upon the rule used in the Ontario Wetland Evaluation System that land under active agricultural use will not be classified as part of a wetland (MNR, 1993). Open shrubland was interpreted as agricultural land in many situations, if it appeared that the area was being used as pasture. This assumption was based on field experience, which demonstrated that pasture land was often composed of grassland scattered with parcels of trees and shrubs. In other situations, the 250 foot (75 metre) contour line taken from the Belleville East, Shannonville, and Deseronto 1:25000 scale topographic maps were used or references were made to where wetland edges were drawn on the 1993 wetland evaluation vegetation maps.

The end result of the aerial photograph analysis was a set of maps that were made by directly tracing vegetation communities identified from the images onto mylar. Different

communities were colour coded to allow easy identification. Unfortunately, these maps represented Big Marsh and the other wetlands at different scales and they were quite distorted. Hence, these factors had to be corrected during the map making process.

E) Map Making Methodology:

All of the interpretation maps had to be converted to one scale and attempts were made to decrease the amount of aerial distortion. It was decided that all of the maps should be changed to a scale of 1:10 000, the scale at which the Ontario Base Maps were drawn, and was the largest scale at which base maps could be obtained. A reflecting projector, which reflected each of the traced vegetation images through a lens onto a base map, was used for this purpose. This system allowed the projected image to be increased or decreased in size from the original tracing, until a scale of approximately 1 : 10 000 had been reached. Human features with an east-west orientation located on the community tracings taken at different time periods and the base map were used as ground controls. The same feature was overlapped by adjusting the size of the reflected image. Railroads and roads were used for this purpose, because they are easily identified, and overlapped. When the anthropogenic features were superimposed over each other, the reflected image was assumed to be at a scale of 1:10 000 and it was traced onto tracing paper. Once again, the communities were colour coded to allow for easy interpretation during the drawing of the final maps.

Planimetric shift was the major factor cause of distortion that remained. This phenomenon resulted in variations of scale in different aerial photographs as well as on different portions of each image, because the photograph was taken from one view point (Campbell, 1991). The two major factors that affect the amount of planimetric shift are: a) height above the level of the photograph; and b) distance from the centre of the image. Since all of the marshes used in this study are located on a plain, planimetric shift caused by topographic variation was not a major cause of distortion. Unfortunately, the technology to regulate aircraft altitude was not as efficient when many of these historic aerial photographs were taken, and this affected the consistency of the altitude at which the series of photographs were taken. Planimetric shift distorted images of communities and other features located on the periphery of the photograph. This problem had the greatest impact upon the maps drawn of Big Marsh, since several different aerial photographs had to be used to draw these maps, and many of the communities were not located close to the principle point. Much of the distortion would have been corrected when the reflecting projector was used to convert the tracings to a 1:10 000 scale.

Once the tracing images were converted to a 1:10 000 scale, the final vegetation community maps used for area calculations were drawn. Since these maps had to be duplicated on microfiche, the methods of presenting the communities was limited to using black and white patterns. Hence, it was decided to use dots to represent open water, horizontal black lines to

symbolize marsh communities, a black grid identified shrub communities, and solid black represented the forest swamp. This pattern was used to represent the different stages of succession, where open water (the lightest) is the earliest step and the tall tree swamp is the final stage.

It is important that the final vegetation community maps do not give the impression of accuracy that is greater than the source material warrants (Kuchler and Zonneveld, 1988). The lack of photographs that portrayed outer edges of Big Marsh in 1929, 1962, and 1978, made it necessary to indicate regions that could not be mapped.

1993 maps of the other marshes were modifications of the vegetation maps that were included in the 1993-1994 inventories of these wetlands. Since these wetland maps were drawn directly onto Ontario Base Maps, it was assumed that the distortion had already been corrected. Since it was not possible to separate the low shrub category and tall shrub category on historic aerial photographs, these communities were combined into one shrub grouping.

F Area Calculations:

Measures of the area changes that occurred in vegetation communities in Big Marsh for each of the study years as well as the other wetlands in 1929 and 1993 were also made. Percentage of cover and total area was calculated for open water, marsh communities, shrub swamps, and tall tree swamps with a dot planimeter on the 1 : 10 000 vegetation maps. A dot planimeter is a transparent overlay that consists of a regular spaced pattern of points, and area was calculated by counting the number of dots that fit onto the area measured and half of those that fell on the boundary (Cambell, 1991). To prevent double counting, each map was covered with a sheet of tracing paper and each section was shaded in after its area was calculated. The overlay used had a degree of precision of 97 % and it was calibrated to calculate square inches. Area was converted into hectares by multiplying the results calculated from the dot planimeter by 6.4516. This ratio was based upon the fact that one hectare is equal to 1 000 square metres, and one square inch is equal to 6.4516 square centimetres.

It must be noted that there is a fairly high probability of error when the area is found for each of the communities. Errors were likely to have occurred when communities were delineated on the historic aerial photographs. Further errors may have occurred when the vegetation maps were converted to a scale of 1 : 10 000. Kuchler and Zonneveld (1988) stated that a distance of one millimetre on a map at a scale of 1 : 10 000 is equal to a distance of ten metres, and an area of one square millimetre is equal to one hundred metres squared. Hence, errors were likely to have been made when calculating the area of the communities. The width of artificial features such as roads and railroads were also enlarged on the original 1 : 10 000 vegetation maps to ensure that they were identifiable on the reduced versions that accompany this document. Hence, this will cause a minor loss of wetland area in a few of the wetlands.

3 RESULTS

A Vegetation Properties

Dominant species from the marsh, shrub swamp and tree swamp communities, and are presented in Table # 1.

a Marsh Communities:

Hartley (1994a) noted that coastal marshes along the Bay of Quinte are characterized by extensive stands of cattails, which are believed to have been more diverse historically. The author's experiences in Big Marsh indicated that the areas that express the most plant diversity are along open water edges, on abandoned muskrat and beaver lodges, and in areas where the cattail community is drying out. These areas are also dominated by jewelweed (Impatiens pallida), nightshade (Solanum dulcamara), marsh milkweed (Asclepias incarnata), black willow (Salix nigra) (juvenile), beggars tick (Bidens frondosa), northern bedstraw (Galium boreale), and European frogbit (Hydrocharis morsus-ranae).

The lack of diversity in most of the cattail stands is attributed to the introduction of large sediment influxes, excessive nutrient inputs, obstructed water flows, and the decreased amplitude of natural water-level fluctuations necessary to maintain marsh diversity. Once these communities are established, they are able to prevent most species from invading until the soil dries out enough for woody species to survive.

The two dominant species of cattails that inhabit these marshes are narrow leaved cattails (Typha angustifolia) and broad leaved cattails (Typha latifolia). Big Marsh is dominated by Typha angustifolia. Typha angustifolia, not native to the region, has spread to the Great Lakes from the Atlantic coast within this century (Grace and Harrison, 1986). It will grow in water to a depth of one metre and its rhizomes do not require air during the winter (McDonald, 1955). Since Typha angustifolia does not have the ability to compete with Typha latifolia in stable environments, it is frequently restricted to habitats that possess an unstable environment (Smith, 1967).

Typha latifolia is a cosmopolitan species that is native to the Great Lakes (Grace and Harrison, 1986). It is limited to water depths that do not exceed thirty centimetres and its rhizomes must be exposed to air during part of the winter. Large die offs have occurred in Typha latifolia during winters with high winter water levels, because its rhizomes can only endure short periods of anaerobic conditions (McDonald, 1955).

A large portion of Big Marsh and probably the other wetlands consists of floating cattail mats. In these sections, the cattail community is not rooted on mineral soil. It floats on fibrous mats that are buoyant enough to hold the weight of a person. According to Bertil and Wein (1988), these mats are very resilient and they recover from the normal range of periodic drying

and burning that occurs in marshes. Hence, the habitat condition of cattail floating mats changes little over long periods of time. Unless they are broken up by storms. Eventually these mats rest on the wetland substrate as organic material accumulates and the mat thickens, unless the cattail mats are broken-up and float away (Bertil and Wein, 1988).

b Shrub Swamp and Tree Swamp:

Woody vegetation was the focus of this study, because this taller vegetation form defined this type of community. Furthermore, woody vegetation is the only form visible on the aerial photographs used. A description of the soil conditions that are suitable for the woody vegetation found in Big Marsh and the study wetlands is made in Appendix # 2.

Periodic flooding influences woody species composition primarily through differential seedling mortality, although shade tolerance, longevity and periodicity of seed production and seed dispersal also play important roles (Kilmas, 1988). According to Kilmas (1988), moderate increases and any decrease in flood duration, frequency, and depth generally do not eliminate forest cover. However, it has been well documented that prolonged waterlogging of soil will eliminate woody species in the Great Lakes region, because these plants require adequate root-zone aeration.

Several factors affect the growth rate of swamp communities. Juvenile populations of tree and shrub species are slow to build-up because propagules are not dispersed as rapidly or as far as those of herbaceous vegetation. Woody vegetation propagules are not represented within seed banks of recently abandoned agricultural land and most early established plant types are transitional species that rely upon wind or bird dispersed seeds (Burrows, 1990). Conditions on open cultivated ground is not suitable for juvenile woody plants and herbaceous communities exclude trees and shrubs by rapid growth in these sites; therefore, out competing them for light.

The dominant and common woody species identified within the shrub and tree swamp communities within Big Marsh are: black willow (Salix nigra), peach-leaved willow (Salix amygdaloides), meadowsweet (Spiraea latifolia), slender willow (Salix petiolaris), (Salix babylonica), black ash (Fraxinus nigra), and red maple (Acer rubrum). All of the woody vegetation identified in Big Marsh and in the other wetlands are adapted to grow in wet conditions. Several species, such as black willow (Salix nigra), white elm (Ulmus americana), and buttonbush (Cephalanthus occidentalis) thrive in situations where the soil is frequently waterlogged. Hence, these communities could survive short periods of wet and even water logged soils.

B Vegetation Changes:

This section presents the vegetation maps that were drawn of Big Marsh and the other wetlands for the study period as well as calculations made for the area occupied by different vegetation communities for these wetlands.

Table # 2: Percentage of Area Occupied by Vegetation Communities
in 1929, 1962, 1978, and 1993, Big Marsh

	Open Water	Marsh	Shrub Swamp	Tree Swamp
1929	8	76	14	2
1962	7	46	22	25
1978	8	32	21	39
1993	9	27	20	44

Table # 3: Percentage of Area Occupied by Marsh and Open Water in the
Study Wetlands in 1929 and 1993

	Open Water 1929	Open Water 1993	Marsh 1929	Marsh 1993
Airport	7	13	93	51
Belleville	2	10	78	64
Blessington	17	16	73	72
Bluff point	0	0	62	36
Lower Sucker	49	70	47	23

Table # 4: Percentage of Area Occupied by Shrub Swamp and Tree Swamp in
the Study Wetlands in 1929 and 1993

	Shrub Swamp 1929	Shrub Swamp 1993	Tree Swamp 1929	Tree Swamp 1993
Airport	0	32	0	4
Belleville	20	0	0	26
Blessington	9	5	1	7
Bluff	24	14	14	50
Lower Sucker	4	6	0	1

Table # 5: Area Occupied by Major Vegetation Communities in Big Marsh For 1929, 1962, 1978, and 1993 (Area in Hectares)

	Open Water	Marsh	Shrub Swamp	Tree Swamp	Total
1929	27	258	49	7	341
1962	29	181	88	94	392
1978	34	134	90	167	425
1993	40	128	92	208	468

Table # 6: Area Occupied by Open Water and Marsh in the Study Wetlands in 1929 and 1993 (Area in Hectares)

	Open Water 1929	Open Water 1993	Marsh 1929	Marsh 1993
Airport	2	4	28	16
Belleville	1	2	28	13
Blessington	20	18	87	80
Bluff	0	0	39	19
Lower Sucker	34	38	32	12

Table # 7: Area Occupied by Shrub Swamp and Tree Swamp in the Study Wetlands in 1929 and 1993 (Area in Hectares)

	Shrub Swamp 1929	Shrub Swamp 1993	Tree Swamp 1929	Tree Swamp 1993
Airport	0	10	0	1
Belleville	7	0	0	5
Blessington	11	5	1	7
Bluff	15	8	8	27
Lower Sucker	3	3	0	1

a Big Marsh:

The area of Big Marsh has increased from approximately 340 hectares in 1929 to about 470 hectares by 1993 (see table # 5). Most of this increase is attributed to the reestablishment of tall tree swamps on the north-western and eastern peripheries of Big Marsh that had been cleared (hence they were not classified as wetland) in 1929. The percentages of Big Marsh occupied by tall tree swamps increased from 2% in 1929 to approximately 44% in 1993. An increase of almost 25% in tree swamp occurred between 1929 and 1968, and another gain of approximately 15% occurred between 1962 and 1978. The rate of succession to this community appears to have slowed, only a 5% increase in tree swamp occurred between 1978 to 1993.

Most of the initial expansion of tree swamp took place on the western shore of Big Marsh and this portion of the wetland was filled with this community by 1962. Currently, tree swamp expansion is occurring in the north-eastern and south-eastern portions of the wetland.

There was little change in the total amount of open water between 1929 and 1993. Marsh communities decreased by almost 30% during the first 33 years of this study. A loss of approximately 15% took place between 1962 and 1978, and a decrease of 5% occurred between 1978 and 1993 (see table # 2). Hence, it appears that little change has occurred in marsh area during the final 15 years of the study (see figures # 3, 4, 5 and 6).

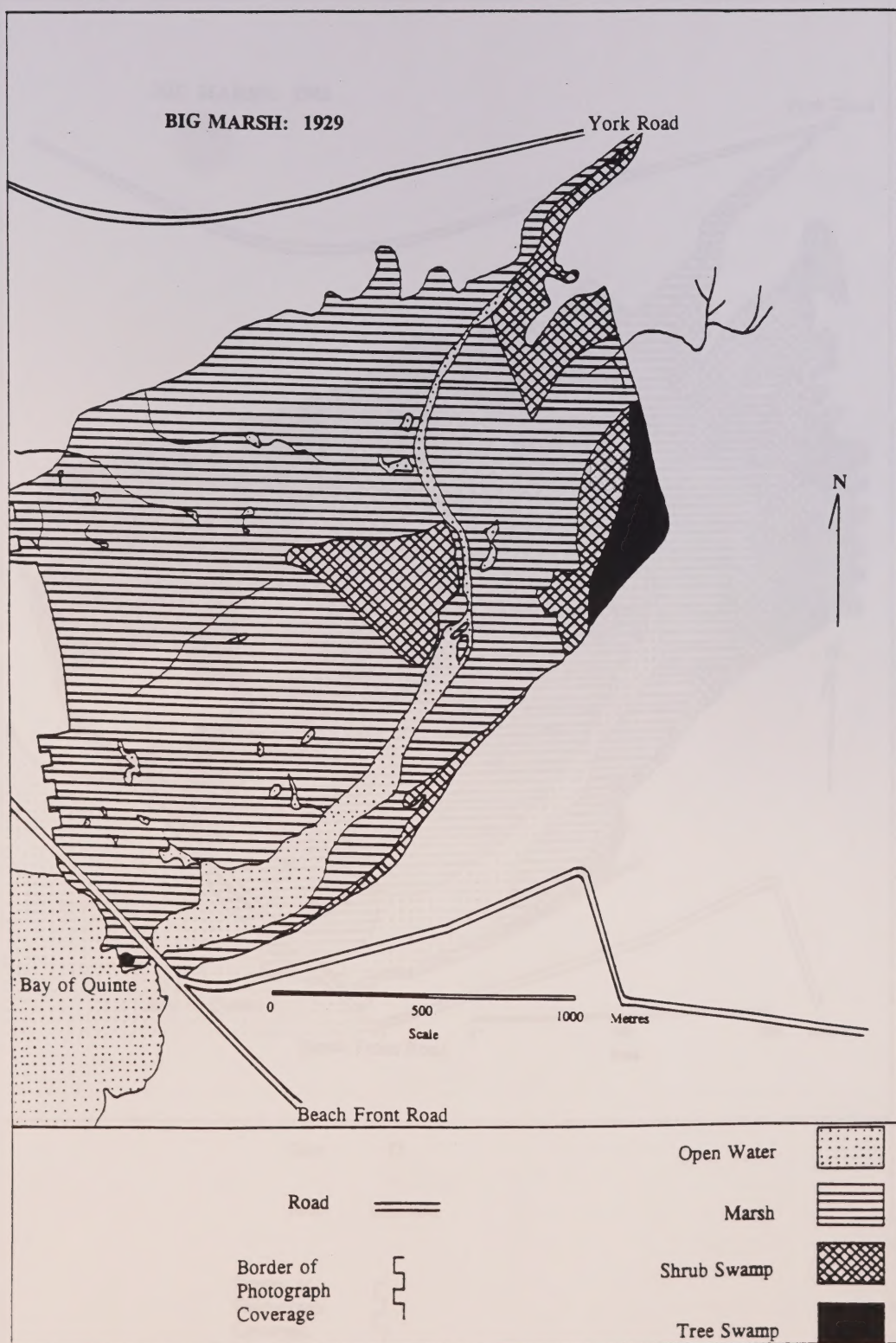
The proportion of shrub swamp has not changed drastically during the 64 year period included within this study, but its distribution has. Shrub swamp has expanded into marsh communities; however, it has itself been replaced by tree swamp. Shrub communities have become established on the western and eastern shores of the wetland. The largest area of this community type is the north-central portion of the marsh. It appears that the largest changes occurred between 1929 and 1978. There have been few changes since then.

With the exception of a decrease in agriculture, there appear to be few other marginal land-use changes in the area that lies within 1.5 kilometres of Big Marsh. Cattle have been observed tearing-up the shoreline and destroying native plants in northern sections of the wetland near York Road. Reilley (1993) observed the use of defoliants to control vegetation along the main Canadian National Railway line in 1993, which was likely to have run off into Mud Creek. He also stated that it is likely that sand and salt used on the major roads were likely to have entered Mud Creek. A number of houses that have also been constructed along York Road during this period.

b Airport Marsh:

The area of Airport Marsh (refer to figure # 7) has increased from 29 hectares in 1929 to 31 hectares in 1993 (see tables # 6 and 7). Open water nearly doubled in extent over the same period, while marsh decreased from approximately 94% to 51%. Shrub swamp was absent in 1929 but currently it covers one third of the wetland. Tree swamp, absent in 1929, now covers about

Figure # 3



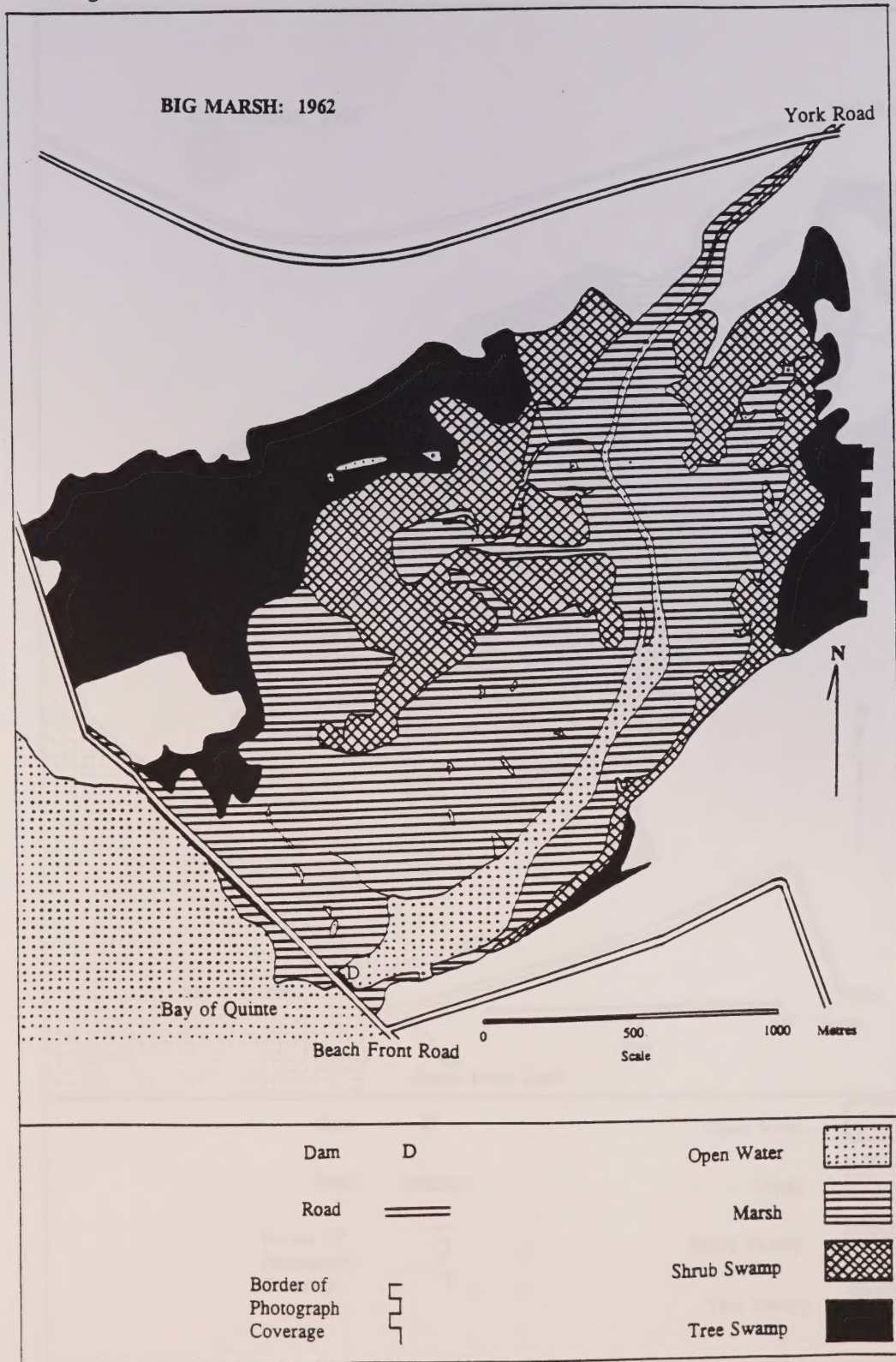
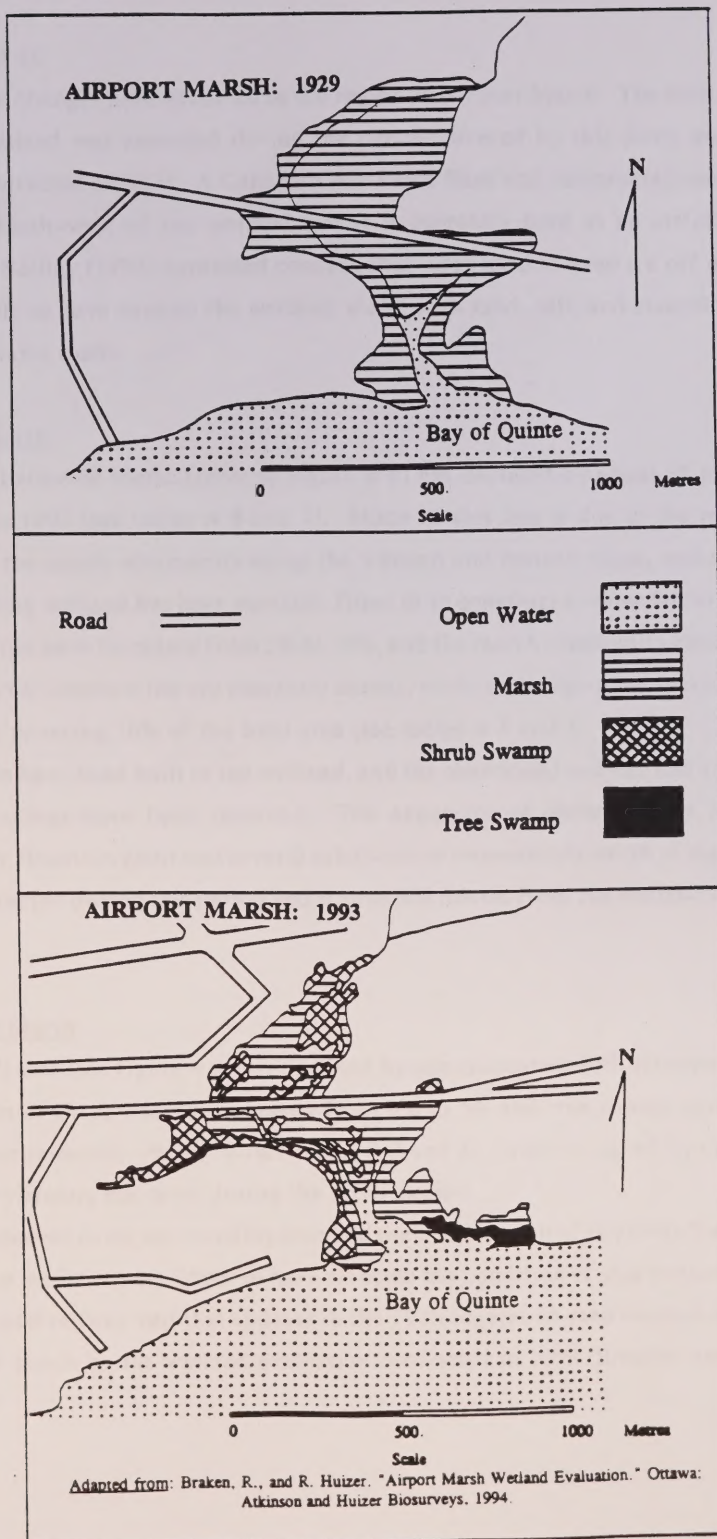




Figure # 6





4% (see tables # 3 and 4).

A few land use changes have occurred in the region of Airport Marsh. The road that runs to the west of the wetland was extended during the period covered by this study and several houses have been constructed along it. A Canadian Air Force Base was constructed near the end of the 1930s to the north-west of the wetland and it is currently used as an airfield by the community college. Reilley (1993) expressed concern that urea used to keep ice off of the runway in the past is likely to have entered the wetland, along with sand, salt, and creosol that have been applied to the major roads.

c Belleville Marsh:

Total area of Belleville Marsh (refer to figure # 8) has declined by about 35 hectares in 1929 to 20 hectares in 1993 (see tables # 6 and 7). Much of this loss is due to the removal of shoreline portions of the marsh community along the western and eastern edges, and the centre portion of the remaining wetland has been partially filled in to construct a water filtration plant. Open water communities have increased from 2% to 10%, and the marsh community has decreased from 78% to 65%. Shrub communities are currently absent, while tree swamp has increased from being non-existent to covering 26% of the total area (see tables # 3 and 4).

Two reservoirs have been built in the wetland, and the abandoned railway bed and several abandoned bridge footings have been removed. The expansion of Belleville has led to the construction the water filtration plant and several subdivisions immediately north of the wetland. Highway 2 was constructed during this period and it runs 300 metres from the wetland's northern boundary.

d Blessington Marsh:

This wetland's area (see figure # 9) has declined by approximately 10% between 1929 and 1993. The proportion of shrub swamp decreased from 9% to 5% and tree swamp communities increased in from approximately 1% to 7% (see tables # 3 and 4). Area occupied by open water and marsh remained virtually the same during the study period.

Urban development in the surrounding area and the construction of Highway 2 within 300 metres of the northern periphery are likely to have affected the condition of this wetland greatly. The southern abandoned railway bed that appears in the 1929 vegetation map remains and it was classified as a barrier beach by the wetland evaluation conducted in 1993 (Bracken and Huizer, 1993).

Figure # 8

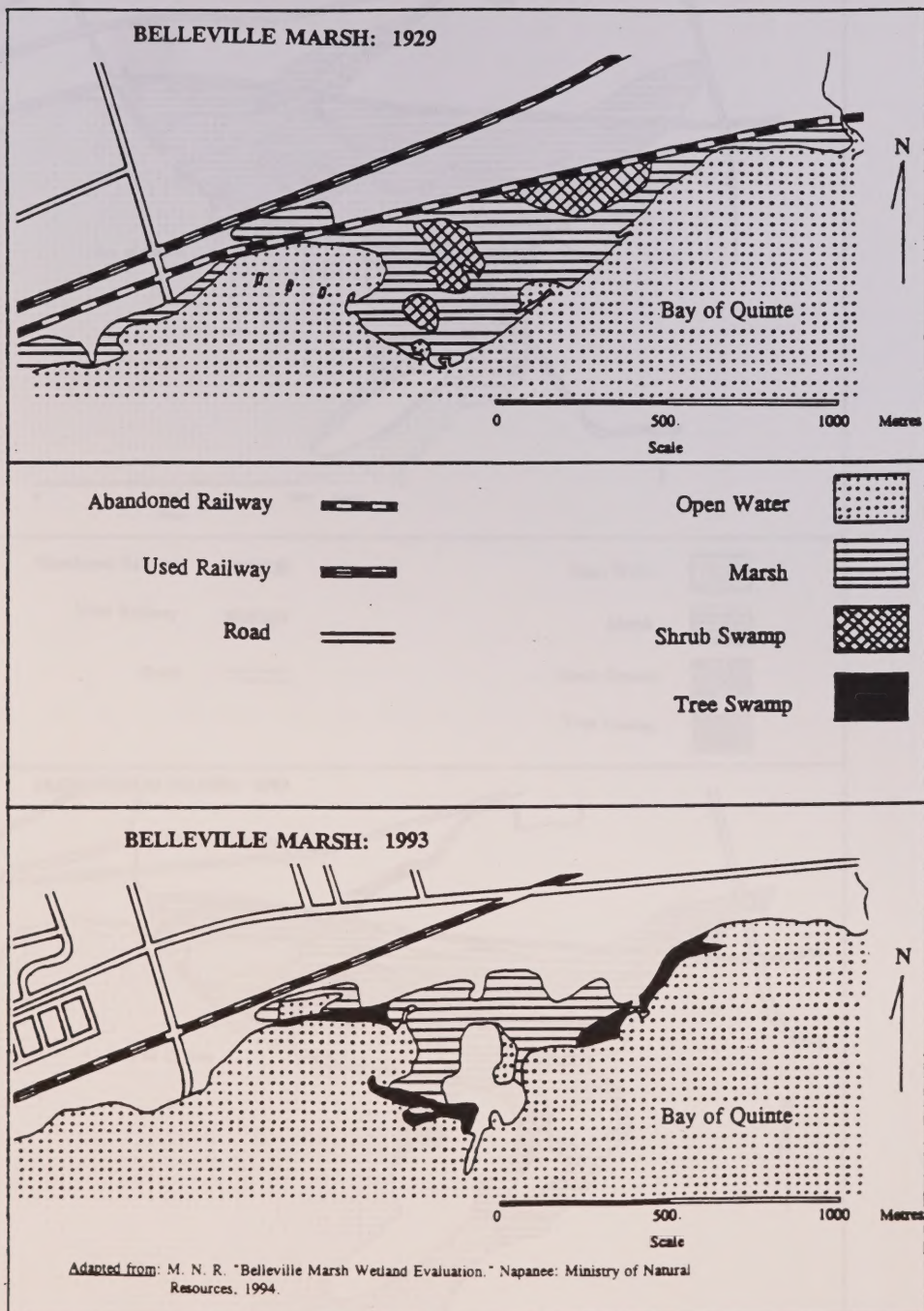
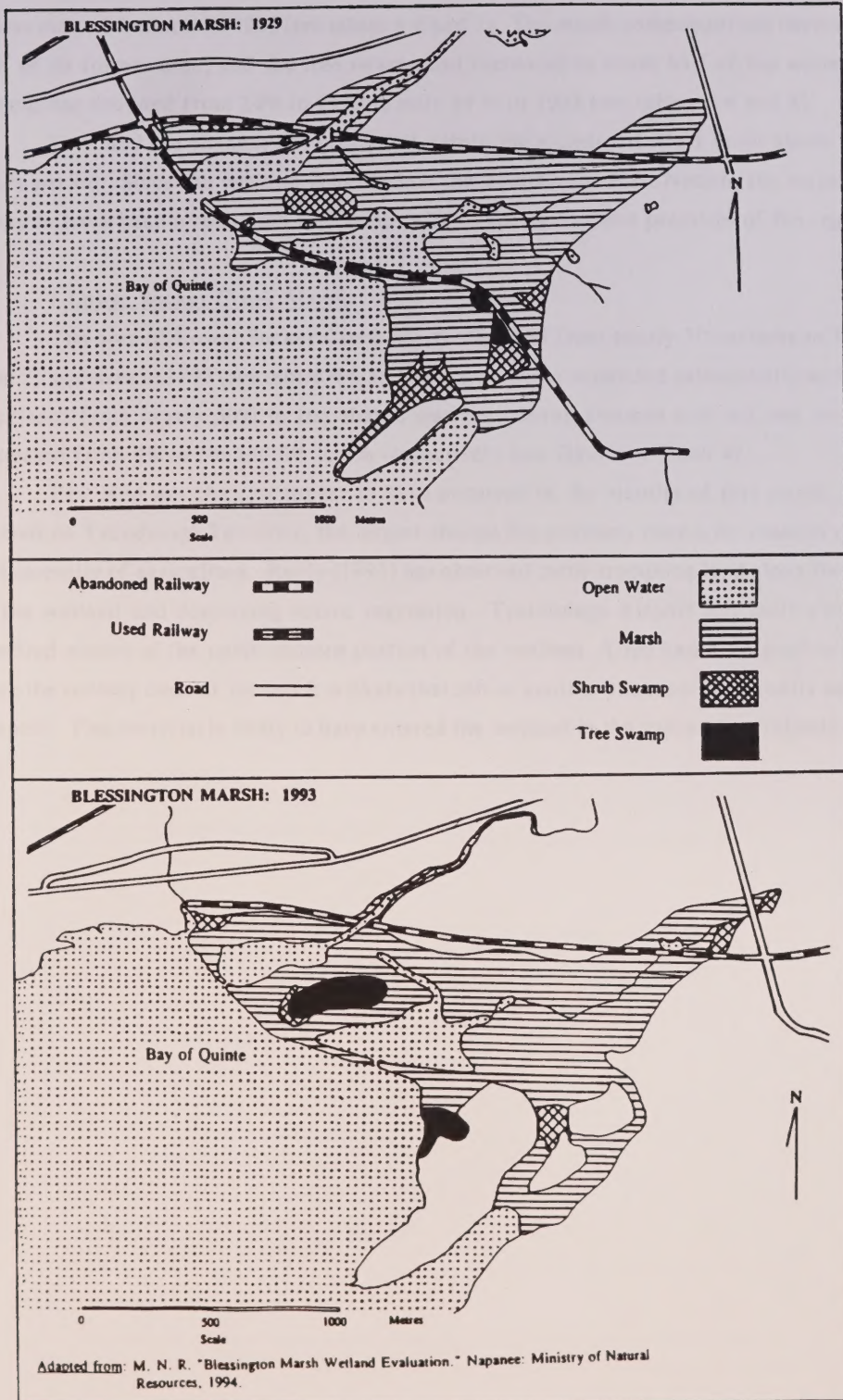


Figure # 9



e Bluff Point Marsh:

Bluff Point Marsh (see figure # 10) has decreased in area from over 60 hectares in 1929 to less than 55 hectares in 1993 (see tables # 6 and 7). The marsh component has decreased almost half of its former area, and the tree swamp had increased to cover half of the wetland. Shrub swamp has declined from 24% in 1929 to only 14 % in 1993 (see tables # 4 and 4).

Few land use changes have occurred within the vicinity of Bluff Point Marsh during the study period. Since the wetland is located on the Tyendinaga First Nation, the major change is likely to have been a reduction in the intensity of the agriculture practices of the region.

f Lower Sucker Creek Marsh:

The area of Lower Sucker Creek Marsh declined from nearly 70 hectares in 1929 to less than 55 hectares in 1993 (see tables # 6 and 7). Open water expanded substantially and marsh has decreased from nearly 50% to less than a quarter. Shrub swamps and tall tree swamps have increased from 4% to 6% and 0% to 1% respectively (see figures # 3 and 4).

Few land use changes appear to have occurred in the vicinity of this marsh. Since it is located on Tyendinaga Territory, the largest change has probably been a decrease in the amount and intensity of agriculture. Reilly (1993) has observed cattle trampling land along the perimeter of the wetland and destroying native vegetation. Tyendinaga Airport was built within several hundred meters of the north-eastern portion of the wetland. Urea had been used in the past to keep the runway clear of ice and it is likely that salt or another chemical is currently used for this purpose. This material is likely to have entered the wetland in the past and it probably continues.



Figure # 10

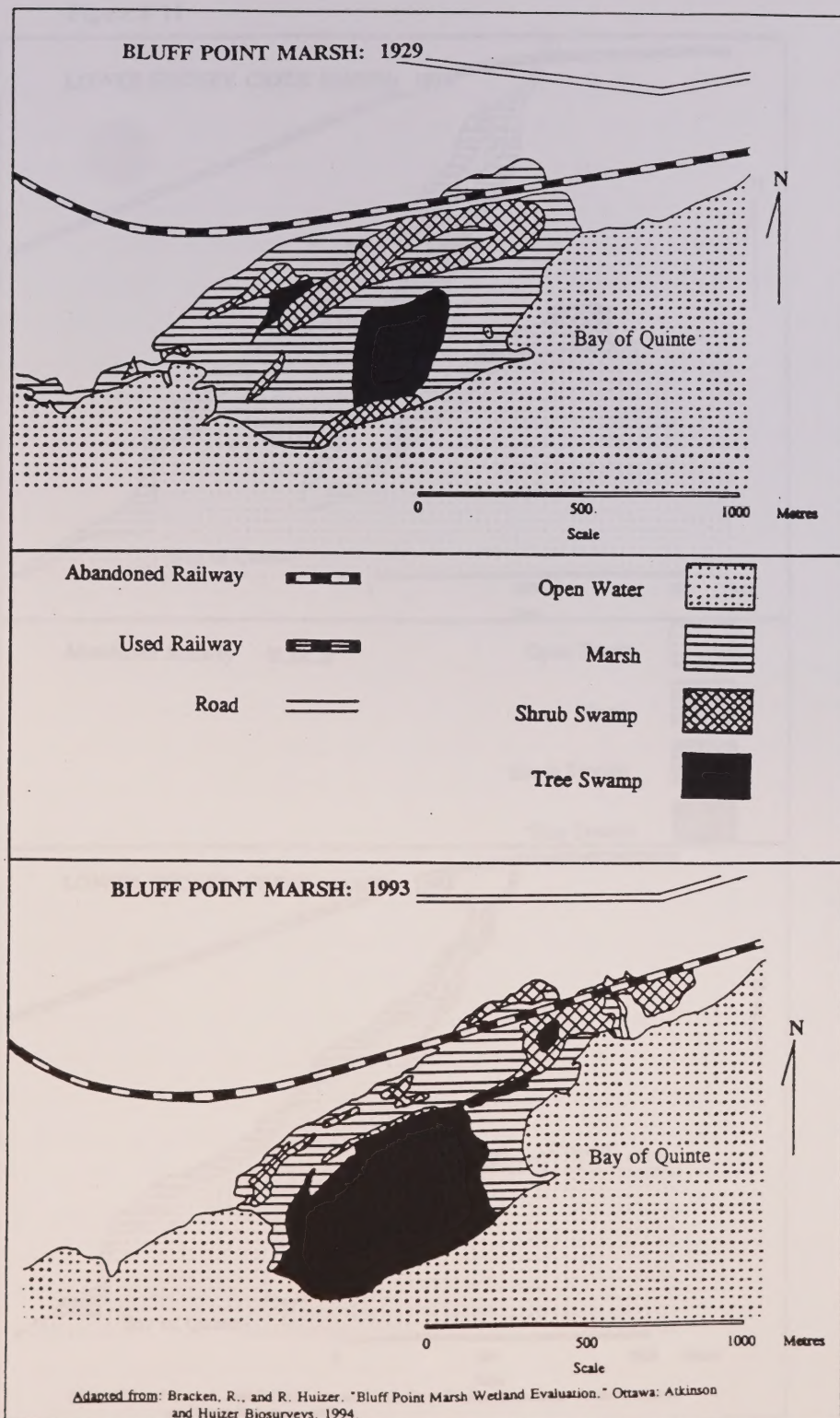
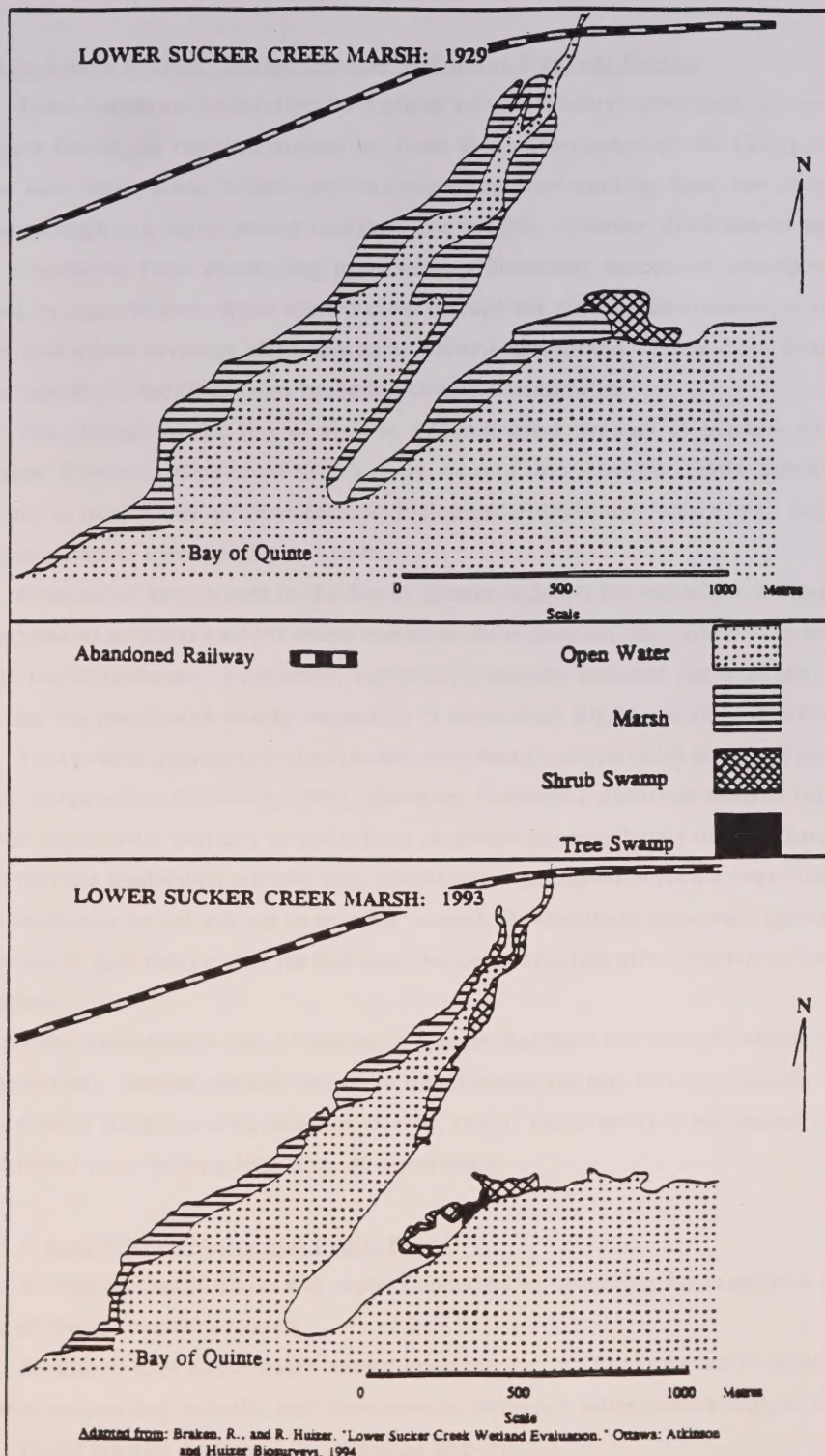


Figure # 11



4 DISCUSSION

A Factors Likely to Have Created Changes Within the Wetlands Studied

These coastal wetlands reflect both primary and secondary successional processes. Primary succession begins, as marsh communities form as a consequence of the filling of protected, shallow near-shore areas, where previous vegetation communities have not existed. It may succeed through to a shrub swamp and then tree swamp; however, disturbances may prevent a marsh community from developing into swamp. Secondary succession processes are usually initiated by disturbances. When disturbances disrupt the existing community, a niche may be formed that allows invading plant species to become established. These disturbances may also prevent marsh communities from becoming swamp communities.

The changes in the Bay of Quinte wetlands are a product of primary and secondary succession. Given the time frame of this study, most of these changes are attributed to the latter. There are several kinds of physical and biological disturbances which may individually or collectively impact these coastal wetlands.

Removal of swamp area in the Bay of Quinte region at the end of the nineteenth century for agricultural purposes enabled marsh communities to develop, that would have been excluded prior to the disturbance. Eventually, secondary processes replaced the emergent species that dominated the marsh with woody vegetation in portions of Big Marsh and the other wetlands.

Tree swamps represent a climax community that should be stable over long periods of time and self-perpetuating (Burrows, 1990). However, frequently disturbed wetland (or sections) of wetlands may remain partially or entirely in an almost perpetual state of non-maturity. Often species that are established initially may inhibit other species from taking over (Niering, 1990). This process may be carried out in marshes through the dominant emergent vegetation limiting the amount of light that reaches the soil layer; hence, preventing other vegetation from becoming established.

When disturbances occur frequently, species that have low rates of reproduction tend to become extinct. Species are also lost when disturbances are rare and the affected communities enter a state of competitive equilibrium (Krebs, 1994). Biodiversity is maximized when systems are subjected to an intermediate level of disturbance.

a Activities of Native and Exotic Fauna:

Several species of native and exotic fauna may be impacting the vegetation communities of Bay of Quinte coastal wetlands.

Livestock have had a major impact upon the Bay of Quinte wetlands. Cattle may cause increased erosion and run-off, and their manure influence water quality (Bay of Quinte RAP, 1989). Plants are also destroyed by trampling and grazing.

Gazing animals select leaves in preference to stem, and green vegetation over dry material (Arnold, 1964). Cattle grazing often affects swamp species by the selected feeding of juvenile plants. If heavy browsing occurs, virtually all saplings, even those of normally unpalatable species may be killed (Burrows, 1990). This is important, because plants are especially sensitive to grazing during their juvenile stage (Smith, 1986). If removal of plant tissue of juvenile or mature trees does not kill the plant immediately, its long term survival is often reduced. Plants that survive grazing are placed at a competitive disadvantage to surrounding vegetation and their reproductive ability is often reduced. Furthermore, replacing lost leaves drains the plant of nutrients and supplies required for the following season (Smith, 1986).

Cattle have been observed along the eastern shore of Big Marsh. In the 1929 aerial photographs, much of the western shore of the wetland may have been used as pasture. Grazing on the western shore seems to have ceased by 1962 and they were not observed during fieldwork. Cattle are also having a direct impact on Lower Sucker Creek Marsh and are likely to have affected Airport Marsh and Bluff Point Marsh over the past 64 years.

Only one example of cattle entering the marsh component of Big Marsh was observed during the field work; however, there were numerous cattle paths through the swamp portion on the eastern side of Big Marsh. Hence, cattle are likely to be the major factor for decreasing swamp expansion through consumption and trampling of juvenile saplings.

Cattle grazing, browsing, and trampling continue to affect Big Marsh and Lower Sucker Creek Marsh. Historically, this factor would have been greater, because more livestock was raised then on the Tyendinaga First Nation. The impacts of livestock are likely to have been greatest in the 1920s and 1930s, when the Great Depression was occurring.

Carp are an exotic fish species that was originally introduced into Lake Ontario in 1877 (Scott and Crossman, 1973), and they were most numerous in the Bay of Quinte in the 1950s (Bay of Quinte RAP, 1989). Klarer and Millie (1992) state that carp may play an important role in determining the aquatic microphyte composition in many Great Lake wetlands, through the uprooting of these plants through feeding and spawning. Large numbers of this species were observed during the spawning period toward the end of June while conducting field work in Big Marsh.

The literature reviewed indicated that carp may have a dramatic effect upon submerged vegetation; however, there were no reports on the effects of the species on emergent vegetation. Hence, it is not likely that carp has changed the marsh community in any of the study wetlands, although it has probably affected open water vegetation communities.

Muskrat has been identified in several literature sources as being a source of marsh destruction. This mammal consumes stems and roots of aquatic vegetation and its major food source is cattails (Burt, 1991). Large bodies of open water have been created in wetlands during eat-outs, when these mammals consume large areas of shallow-rooted cattail rhizomes (McCabe

and Wolfe, 1988). The creation of these openings has also been identified as a means of allowing plants to invade a marsh that would not have survived if the cattail stand was present, such as woody vegetation (McCabe and Wolfe, 1988).

The number of muskrat trapped in any year depends largely upon the price of their pelts. During the late 1930s, a good muskrat pelt was worth between \$0.50 to \$0.75. This value increased to between \$4.00 and \$5.00 during World War Two (1939-1945), and the price declined to approximately \$2.00 after the war ended (Bullock, 1994). Currently, the value of muskrat pelts is so low that the number of these mammals being trapped has decreased to virtually zero (Maracle, 1994).

Muskrat are preyed upon by mink, birds, mammals, and humans; however, Burt (1991) claims that they are able to survive and increase in numbers whenever suitable habitat is available. Hence, it is not likely that human predation has ever affected muskrat populations. Population patterns seem to follow a natural cycle and the only factor that appears to affect this cycle is the amount of habitat available (Sauguin Marsh Research Meeting, 1994). Area residents that have spent much time in Big Marsh or other wetlands in the region have claimed that they have never observed large-scale clearance of cattail marsh by muskrat.

b) Exotic Plants:

Four exotic plants have affected the wetlands in the Bay of Quinte Area. These species are: a) purple loosestrife (Lythrum salicaria); b) Eurasian watermilfoil (Myriophyllum spicatum); c) European frog-bit (Hydrocharis morsus-ranae); and d) narrow-leaved cattail (Typha angustifolia).

Purple loosestrife and Eurasian watermilfoil have not drastically affected the vegetation communities included in this study. Eurasian watermilfoil is an aquatic plant that would not have impacted marsh or shrub communities. Purple loosestrife has not been able to penetrate the cattail stands in great amount in any of the study wetlands, as observed during the field work and noted in the wetland evaluations.

European frog bit was imported to Ottawa from Switzerland in 1932 and it reached the Bay of Quinte in 1972 (Mills et al., 1993). This species occupies a niche that is quite similar to that of duckweed (Spirodela polyrhiza; and Lemna sp.). It floats on open water and grows densely in cattail stands. Currently little is known about the ecological effects of this species, and further research must be conducted in order to evaluate its effect upon wetland vegetation communities.

Narrow-leaved cattail (Typha angustifolia) was originally native to Eurasia and it was brought to North America by the earliest European colonists. This species of cattail became established in Lake Ontario in the 1880s (Mills et al, 1993). Currently, it is the major marsh species in Big Marsh as well a portions of the other wetlands. It has out competed the native Typha latifolia in many of the Bay of Quinte coastal marshes, and may be partially responsible

for the decline of vegetation diversity that previously existed in these wetlands. However, Typha angustifolia has not been able to resist invasion by swamp communities in many situations. It is possible that Typha angustifolia has been able to slow the advance swamp through killing juvenile woody vegetation by preventing enough light from reaching them.

c Water Level Fluctuations:

Vegetation patterns within Great Lake coastal wetlands are largely determined by water levels. Long term high water levels prevent invasions of these wetlands by terrestrial and woody species (Klarer and Millie, 1992). When the roots of woody vegetation are inundated, the oxygen supply to the roots rapidly decreases, which shuts down aerobic metabolism, impairs the energy status of cells and reduces nearly all metabolically mediated activities, such as cell extension, division, and nutrient absorption. Prolonged shifts to anaerobic glycolysis often leads to an accumulation of toxic end products that often kills the plant (Mitsch and Gosselink, 1993). Organic and fine mineral particles (such as silt and clay) may be removed by water circulation, mud flat species disappear, and emergents and other plants not tolerant to flooding die out (Keddy and Reznicek, 1986). Lower water levels will usually change wetland vegetation patterns dramatically, as vegetation that is intolerant to drying out dies and is replaced by species emerging from buried seeds (Wilcox, 1993). These periods also allow species to replenish seed banks to ensure regeneration during the next dry period (Keddy and Reznicek, 1986). Decomposition rates of organic material in the wetland substrate is often increased as well.

A reduction in the intensity and frequency of water level changes often increases the dominance of woody plants and cattails present in the wetlands and leads to the loss of species which regenerate during low water periods (Keddy and Reznicek, 1986). Great Lakes marshes are generally adapted to long twenty-year and short annual cycles. Annual cycles are caused by seasonal changes of runoff into the lakes, when highest levels are recorded in late spring and the lowest occur during the winter. When water level fluctuations decrease, cattail mats tend to increase (Conestoga Rovers, 1992).

Water levels in the Bay of Quinte have been influenced by human activity. The major factor has been the building of a series of dams at Cornwall, Ontario. Construction of these structures began in 1960 and they succeeded in regulating Lake Ontario water levels by 1973 (Ecological Services, 1992). It must be noted that regulating water levels has resulted in a reduction in the magnitude of fluctuations, not an elimination of water levels changes.

To study the potential impact of water level changes, minimum, maximum, and mean water level changes that occurred within ten years and two years prior to the year that each series of aerial photographs were analyzed. A ten year interval is likely to span the longer term fluctuations required for vegetation community changes to occur within coastal wetlands (Mitsch, 1992). A two year period was used to account for any short term changes in the coastal wetland

study conducted by Ecological Services For Planning Limited (1992), and this time period was used here. Minimum and maximum water levels for each year involved in this study were obtained from the closest Canadian recording station at Kingston, Ontario. This source provided information from 1916 to 1989 (Lloyd and Yee, 1989), and monthly mean levels taken from 1920 to 1993 from the Kingston station were obtained from the Great Lakes Water Level Communications Centre (see appendix # 3).

The following charts present the highest and lowest water levels that occurred during the study periods, as well as the averages of the minimum and maximum values recorded during these time periods.

Table # 8: Ten Years Prior to Each Historic Aerial Photograph (Metres Above Sea Level)

	Extreme Min	Extreme Max	Average Min	Average Max
1920-1929	74.0	75.3	74.2	74.7
1953-1962	74.0	75.3	74.4	74.9
1969-1978	74.2	75.4	74.4	75.0
1984-1993	74.3	75.6	74.4	75.1

Table # 9: Two Years Prior to Each Historic Aerial Photograph (Metres Above Sea Level)

	Extreme Min	Extreme Max	Average Min	Average Max
1928-1929	74.5	75.3	74.6	75.1
1961-1962	74.2	74.8	74.3	74.8
1977-1978	74.2	75.1	74.2	74.9
1984-1993	74.4	75.6	74.4	75.3

Table # 10: Ten Year Ranges Between Minimum and Maximum Water Levels (Metres Above Sea Level)

1920-1929	1953-1962	1969-1978	1984-1993
1.3	1.2	1.2	1.3

Table # 11: Ten Year Ranges Between Average Minimum and Average
Maximum Water Levels (Metres Above Sea Level)

1920-1929	1953-1962	1969-1978	1984-1993
0.5	0.5	0.5	0.7

Table # 12: Two Year Ranges Between Minimum and Maximum Water Levels
(Metres Above Sea Level)

1928-1929	1961-1962	1977-1978	1992-1993
0.9	0.6	0.9	1.2

Table # 13: Two Year Ranges Between Average Minimum and Average
Maximum Water Levels (Metres Above Sea Level)

1928-1929	1961-1962	1977-1978	1992-1993
0.5	0.5	0.6	0.9

Table # 14: Ten Year Range Between Minimum and Maximum Mean Values
(Metres Above Sea Level)

1928-1929	1961-1962	1977-1978	1992-1993
0.7	0.7	0.5	0.4

Table # 15: Ten Year Average Mean Water Levels (Metres Above Sea Level)

1928-1929	1961-1962	1977-1978	1992-1993
74.7	74.8	74.9	74.9

Table # 16: Two Year Average Mean Water Levels (Metres Above Sea Level)

1928-1929	1961-1962	1977-1978	1992-1993
0.5	0.5	0.6	0.9

Little change has occurred between the extreme minimum or extreme maximum values. The range between the greatest minimum values was 0.3 metres, while the same range was found between the greatest maximum values taken during the four ten-year study periods. During the four two-year study periods, the range between the largest minimum values was 0.3 metres, and the range between the greatest minimum values was 0.8 metres. Ranges between minimum and

maximum values for each of the ten year periods remain within 0.1 metres of each other, and the largest range between the two year intervals was 1.2 metres. The ten year range between average minimum levels and average maximum levels is 0.2 metres and the correlating range for the two year study periods is 0.4 metres.

Results taken from the monthly mean values are slightly different. The ten year ranges between minimum and maximum mean levels has decreased from 0.7 metres in the 1920-1929 period and 1953-1962 period to 0.4 metres in the 1984-1993 period. Ten year average mean water levels remain within a range of 0.2 metres and the two year average mean water levels fit within a range of 0.4 metres.

As a result, there has not been a drastic change in water levels over this study period. However, ten year average annual mean levels have decreased from fluctuating between 0.7 metres to 0.4 metres. The reduction in water fluctuations over the last 20 years should have increased the rate of succession to swamp communities in Big Marsh and the other Bay of Quinte wetlands; however, the data presented here indicate that the expansion of swamp communities has slowed down after 1978.

The 20 year period of reduced water fluctuation may not be long enough for vegetation community to respond to the change. A lag is likely to occur in the advance of swamp communities, because marsh vegetation slows the invasion of woody vegetation, and shrubs and trees require several years to grow to a height where they will be classified as shrub and tree swamp.

Seiches are another factor that affect water levels in the Bay of Quinte. These are short period water level oscillations created by wind action (Mitsch, 1992). Water level increases may last for periods of less than an hour to several hours on the Great Lakes (Burton, 1985). Sudden increases of 0.5 metres have been observed in the Napanee River--located thirteen kilometres east of Big Marsh (Conestoga Rovers, 1992), and seiches were often observed at the Big Marsh dam. Unfortunately, there have not been any direct measurements taken of water level changes within Big Marsh.

Two other factors affecting water levels within Big Marsh and the other wetlands are changes in input from the rivers that feed them, and the presence of obstructions that may impede water exchange between the wetlands and the bay. Removal of the original forest cover during the nineteenth century has altered flow patterns within the streams flowing into the Bay of Quinte. Their previous flow was relatively stable through out the year. This has shifted to the spring flood and summer low flow conditions that currently exist (Bay of Quinte RAP, 1989).

Water levels within Big Marsh have not been regularly controlled by the dam that was constructed in 1962. Stop-logs occasionally placed within the dam spillway have degenerated to the point where they are not watertight and water levels within Big Marsh appear to be little affected by them (Northardt, 1994). The causeway is likely to have affected water level changes

within Big Marsh by reducing the impact of seiches and by protecting Big Marsh from wave action. However, there is still a small opening at the dam that allows water level changes in the Bay to impact Big Marsh, when the stop-logs are not used. This causeway is likely to have caused some retention of silt that would have escaped into the Bay (Northardt, 1994).

Marshes are more likely to fill in if there is a reduction in the length and number of high water level periods experienced. High water levels are likely to eliminate woody vegetation that may have become established in the area, and prevent the establishment or expansion of swamps. Measurements from this study make it clear that open water areas are increasing in most of the wetlands. Open water has progressively increased in Big Marsh by 27 hectares in 1929, to 29 hectares in 1962, 34 hectares in 1978, and 40 hectares in 1993. There was also a doubling of open water area in Airport Marsh and Belleville Marsh between 1929 and 1993, and an increase in Lower Sucker Creek Marsh (34 hectares in 1929 to 38 hectares in 1993).

d Eutrophication:

When the Bay of Quinte became hypereutrophic, wetland flora that benefitted from the input of phosphorous and other nutrients were able to dominate over other species. This led to a decrease in plant diversity (Bay of Quinte Preliminary Notes, 1988). This hypereutrophic state reduces the amount of dissolved oxygen present in Bay of Quinte and may decrease the cycling of nutrients through bacterial metabolism. Hence, eutrophication may be responsible for a decrease in the availability of inorganic nutrients required for photosynthesis in coastal wetlands (Wetzel, 1983).

Secchi disk readings taken from the upper bay in the 1960s were less than 0.3 metres. These low readings were largely caused by an abundance of blue-green algae blooms which thrived on high nutrient inputs (Johnson and Hurley, 1986). Construction of sewage treatment plants and the addition of secondary treatment to four of them, has reduced the total input of phosphorous levels in the upper bay between 28% to 28% (Robinson, 1986). However, the Bay of Quinte remains eutrophic. Secchi disk readings (presented in appendix # 4) taken from the upper portion of the Bay of Quinte have indicated that nutrient levels in bay water decreased between 1972 and 1987. Secchi values would be higher if they were dependent purely upon current additions; however, nutrients are being released from sediment that had been deposited before the inputs were reduced (Crisman, 1989). In the present decade, control of the phosphorous budget in the upper bay has switched from external sources from the tributaries, to internal loading from sediment. Current phosphorous levels in upper bay sediments are two to three time higher than they were in the beginning of the nineteenth century (Johnson and Hurley, 1986). Another factor to consider is that the major input of nutrient into the Bay of Quinte is from non-point sources that are not affected by the construction of sewage treatment plants.

Nitrogen, phosphorous, and potassium are the nutrients required in the largest quantities

by plants (Arms and Camp, 1988). Plant species quality and diversity are frequently limited by the quantity of required nutrients that are in the shortest supply, even if other nutrients are present in excess of individual plant needs. In temperate aquatic ecosystems, phosphorous is usually the limiting nutrient (Harper, 1992).

Phosphorous is not a highly mobile element and it lacks a mechanism for long distance transfer. Hence, inputs into the Bay of Quinte must arrive from local sources (Krebs, 1994). According to the Bay of Quinte RAP Coordinating Committee (1993), 70% of the phosphorous loads enter the bay through its rivers. Ecologistics Limited (1988) has predicted that 79% of the phosphorous loadings originated from agricultural activities. During the course of transport, 40-60% of the phosphorous is removed from the water column by the settling of sediment particles, absorptions by bed sediments, and biological uptake. The Bay of Quinte RAP Coordinating Committee has listed the following phosphorous loads for the tributaries that feed Blessington Marsh, Big Marsh, and Lower Sucker Creek for the period that ranged between June and October, 1991 (1993):

Table # 17: Phosphorous Levels in Study Tributaries

Tributary Name	Area (Km ²)	Flow (Litres ⁻¹)	Mean Total phosphorous Load (Kg/Day)
Blessington Creek	61.3	45.3	6.9
Mud Creek	56.0	41.6	2.0
Sucker Creek	139.0	102.4	5.1

The mean phosphorous load of 2 kg/day delivered by Mud Creek to Big Marsh are low compared to most of the rivers and creeks in the region because the basin's low relief and relatively low intensity agriculture practices. Factors affecting the nutrient input into Big Marsh during this study are: contamination from septic tanks and the infiltration of cattle faecal material (Green and Hill, 1992). Airport Marsh and Lower Sucker Creek Marsh are likely to have received nutrients through these sources as well as an influx during the spring melt from urea that was added to the Tyendinaga Airport to keep its runways free of ice (Reiley, 1993).

Nutrient inputs are not likely to harm wetland vegetation. Wetland systems can tolerate conditions associated with high nutrient inputs, such as oxygen depletion in the soil, and effective removal or transformation of nutrients through these conditions (Bastion and Benforado, 1988). The increasing nutrients entering Bay of Quinte wetlands are likely to have accelerated the rate at which marsh biomass has accumulated. Gosselink and Turner (1978) claim that wetland systems generally produce more material through primary production than is lost. This is likely to have led to increase organic material and eventually anchor the formerly floating cattail mats.

Eventually, this may facilitate the expansion of woody vegetation; through drying of the substrate. As marsh elevation increases, the frequency and depth of flooding waters decrease and less organic material is exported (Gosselink and Turner, 1978). This leads to further increase in marsh height, resulting in the drying out of the cattail communities and enabling woody vegetation to become established.

Eutrophication may have increased the loss of marsh communities to woody vegetation in all of the study marshes, with the exception of Blessington Marsh. Impacts from eutrophication would have reached a peak in the 1960s, prior to the addition of secondary treatment on Bay of Quinte sewage treatment plants and before the intensity of agriculture began to decrease. Although it has decreased slightly in the upper bay, it continues to be a major factor.

Eutrophication is likely to have been a major factor affecting the succession of communities within Big Marsh. Clause (1994) noted that he has observed a drying of portions of the marsh and the development of shrub swamp in these areas. This is likely to have been affected by an increase in the accumulation of organic matter attributed to a greater abundance of nutrients.

e Siltation:

Removal of forest cover and a conversion of much of the land in the Bay of Quinte Region is likely to have increased erosion. Erosion rates increased when the major crop grown in the area switched from barley to corn, which exported more soil into the Bay of Quinte.

Although wetlands on the Tyendinaga First Nation were subjected to increased sedimentation through land clearance, the predominance of cattle over crop cultivation would have resulted in lower erosion levels into Mud Creek and Sucker Creek than into Blessington Creek and other tributaries located off of the First Nation.

If the profile of Big Marsh indicated in the Figure # 2 is correct, the wetland has filled in drastically between the period prior to the construction of the railway and that covered by the aerial photographs. Sedimentation within the main channel may have been increased due to the construction of the causeway and dam. These structures would have reduced the velocity of Mud Creek and led to a deposition of material that would have been carried out into the Bay of Quinte. Clause (1994) states that the main channel of Big Marsh has filled in substantially during the past thirty years, but this is not supported by the aerial photographs.

Other factors affecting sedimentation of Big Marsh is that sand is being transported into the wetland by seiches and being deposited there, when the dams stop-logs are not in place (Northardt, 1994). Furthermore, vegetation acts as a silt trap, particularly at the edge of marshes, and this increases the sedimentation rate and raises the elevation of the marsh (Gosselink and Turner, 1978).

It must be noted that no significant infilling seem to have occurred in Sucker Creek (see Figure # 2). Sucker Creek is located on the First Nation and it is affected by similar land uses as Big Marsh. Hence, the greater amount of filling in of Big Marsh may be partially attributed to increased sedimentation caused by the causeway and dam.

Sedimentation would have had the greatest impact on Big Marsh and the other wetlands at the end of the nineteenth century, when intensive land clearance increased the run-off of clay and silt into Mud Creek, Sucker Creek, Blessington Creek, and eventually the Bay of Quinte. Construction of the causeway at Big Marsh and Blessington Creek Marsh are likely to have increased siltation as well, by slowing down water velocity in Mud Creek and Blessington Creek. By the time that the 1929 aerial photographs were taken, the rate of siltation appears to have decreased, because there have not been any decrease in open water.

5 CONCLUSIONS

Changes in the area occupied by open water, cattail marsh, shrub swamps, and tall tree swamps between 1929 and 1993 act as useful indicators of environmental changes that occurred in Big Marsh and other Bay of Quinte wetlands. Big Marsh has filled in drastically over the last sixty-three years. Marsh communities currently occupy only half of the area that they had in 1929. This community was replaced by shrub swamp and many of the earlier shrub swamps succeeded into tall tree swamp communities. Area occupied by shrub swamp doubled between 1929 and 1993, the major change being the extension of tree swamps.

The amount of open water increased in all of the study marshes, with the exception of Blessington Marsh. Area occupied by woody vegetation--shrub swamp and tall tree swamp--increased in all of the other marshes.

Analysis of the biological disturbances indicates that only cattle have had much impact on the Bay of Quinte wetlands. The four wetlands most likely impacted are Airport Marsh, Big Marsh, Bluff Point, and Lower Sucker Creek Marsh, which have experienced large increases in woody vegetation. However, the intensity of raising livestock on Tyendinaga First Nation has decreased between 1929 and 1993. This has led to a decrease in the numbers of cattle grazing and trampling wetland vegetation.

Of the exotic plants, Typha angustifolia and Hydrocharis morsis-ranae have become abundant. The success of Typha angustifolia has not halted the progressive contraction of marsh communities. Unfortunately, little is known about the effects of Hydrocharis morsus-ranae upon major wetland vegetation communities.

Water level fluctuations have impacted all of the wetlands included in this study. An increase has been recorded in the mean annual water levels calculated for the ten year study periods and a decrease in the range of mean annual values has also taken place. However, vegetation community patterns have not altered drastically as a result of this change. Construction of the causeway and dam across the mouth of the wetland is likely to have increased the amount of siltation that has occurred within Big Marsh between the period where the railway was constructed and the earliest aerial photographs. The wetlands may be infilling, but there have been no changes in the proportion of open water in them. However, Big Marsh has experienced the largest loss of marsh area to woody vegetation. Since the land-use in the drainage basin of Mud Creek has never been affected by many row crops, it is surprising that Big Marsh has filled in more than Blessington Marsh. Furthermore, Sucker Creek is affected by similar land uses, and Lower Sucker Creek Marsh has not filled in. Lower Sucker Creek Marsh has retained the same basic profile that it possessed in the 1820 (see Figure # 2), while the profile of Big Marsh has changed significantly.

Increased nutrient input from run off and the Bay of Quinte are likely to have impacted all of the subject wetlands. The increased nutrient inputs may be a partial reason for infilling.

The major limitations to this study has been a lack of time and experience. The poor quality of the 1929 aerial photographs may have affected the vegetation maps drawn of this time period. Their poor quality prevented the use of a stereoscope and texture for identifying communities. Not having access to programs or equipment designed to correct planimetric shift is another limitation, although use of the reflector projector and Ontario Base Maps has reduced distortion. Lastly, working with small scale photographs and 1 : 10 000 scale vegetation maps may have decreased the accuracy of the delineation of different vegetation communities, and may have affected the final results that were calculated.

Obtaining information on the vegetation communities present in the Big Marsh and the other Bay of Quinte Coastal wetlands prior to major human impacts after 1820 and prior to the construction of the railway in the 1890s would have been very informative. Using cores to measure of the amount of siltation that has taken place as a result of construction of the causeway and the dam would have provided much useful information. It would also have been interesting to map land use changes that occurred during the study period, and preferably back to 1820, as well as changes in nutrient inputs into Mud Creek, Sucker Creek, and Blessington Creek.

The methodology used for this study may be applicable for studies of other Great Lakes coastal wetlands. Many of the factors that have altered Big Marsh and the Bay of Quinte wetlands affect the other Great Lakes wetlands; however, their effects have been greatest in Lake Ontario and Lake Erie. The largest threats are from agriculture, water level control, eutrophication, and urbanization. Approximately 35% of the marshland along the Canadian shoreline of Lake Ontario, Lake Erie, and Lake St. Clair have been lost over the last two hundred years (Van Patter and Hilts, 1985).

Appendix # 1: Dominant Plant Species Within the Marsh, Shrub Swamp, and Tree Swamp
Communities of the Study Wetlands

Airport Marsh Dominant Species

Marsh	Shrub Swamp	Tree Swamp
<u>Typha angustifolia</u> <u>Carex utriculata</u> <u>Hydrocharis morsus-ranae</u> <u>Spartina pectinata</u> <u>Phalaris arundinacea</u> <u>Carex stricta</u> <u>Calamagrostis canadensis</u> <u>Spiraea alba</u>	<u>Fraxinus pennsylvanica</u> <u>Cornus stolonifera</u> <u>Spiraea alba</u> <u>Salix petiolaris</u> <u>Fraxinus nigra</u> <u>Cornus racemosa</u> <u>Carpinus caroliniana</u>	<u>Cornus obliqua</u>

Adapted from: Bracken, R., and R. Huizer. "Bluff Point Marsh Wetland Evaluation." Ottawa: Atkinson and Huizer Biosurveys, 1994.

Belleville Marsh Dominant Species

Marsh	Shrub Swamp	Tree Swamp
<u>Typha latifolia</u> <u>Impatiens capensis</u> <u>Lemna minor</u> <u>Limnobiium spongia</u> <u>Solidago sp.</u> <u>Cornus stolonifera</u> <u>Lythrum salicaria</u> <u>Verbena hastato</u> <u>Galium palustre</u>		<u>Salix nigra</u> <u>Fraxinus nigra</u> <u>Acer saccharinum</u> <u>Rhamnus cathartica</u> <u>Cornus stolonifera</u>

Adapted from: M.N.R. "Belleville Marsh Wetland Evaluation." Napanee: Ministry of Natural Resources, 1994.

Blessington Creek Marsh Dominant Species

Marsh	Shrub Swamp	Tree Swamp
<u>Typha latifolia</u> <u>Phalaris arundinacea</u>	<u>Ulmus americana</u> <u>Fraxinus nigra</u> <u>Salix sp.</u> <u>Cornus racemosa</u> <u>Cephalanthus occidentalis</u>	<u>Fraxinus nigra</u> <u>Salix sp.</u>

Adapted From: M.N.R. "Blessington Creek Marsh Wetland Evaluation." Napanee: Ministry of Natural Resources, 1994.

Bluff Point Marsh Dominant Species

Marsh	Shrub Swamp	Tree Swamp
<u>Typha angustifolia</u> <u>Scirpus acutus</u> <u>Hydrocharis morsus-ranae</u> <u>Typha latifolia</u> <u>Phalaris arundinacea</u> <u>Sparganium sp.</u> <u>Spirodela polyrhiza</u> <u>Carex stricta</u> <u>Polygonum amphibium</u> <u>Bidens cernua</u> <u>Calamagrostis canadensis</u> <u>Scirpus validus</u> <u>Potentilla anserina</u>	<u>Salix petiolaris</u> <u>Spiraea alba</u> <u>Cornus racemosa</u> <u>Fraxinus pennsylvanica</u>	<u>Populus tremuloides</u> <u>Fraxinus pennsylvanica</u> <u>Cornus racemosa</u> <u>Fraxinus nigra</u> <u>Spiraea alba</u> <u>Cornus obliqua</u> <u>Salix petiolaris</u>

Adapted from: Bracken, R., and R. Huizer. "Bluff Point Marsh Wetland Evaluation." Ottawa: Atkinson and Huizer Biosurveys, 1994.

Lower Sucker Creek Marsh Dominant Species

Marsh	Shrub Swamp	Tree Swamp
<u>Typha angustifolia</u> <u>Scirpus validus</u> <u>Phalaris arundinacea</u> <u>Leersia oryzoides</u> <u>Impatiens capensis</u> <u>Polygonum amphibium</u> <u>Carex stricta</u> <u>Campanula aparinoides</u> <u>Carex uticulata</u> <u>Calamagrostis canadensis</u> <u>Cornus obliqua</u> <u>Spiraea alba</u> <u>Polygonum hydropiperoides</u> <u>Alisma plantago-aquatica</u> <u>Lythrum salicaria</u>	<u>Cephalanthus occidentalis</u> <u>Cornus obliqua</u> <u>Salix petiolaris</u> <u>Spiraea alba</u> <u>Acer saccharinum</u>	<u>Salix fragilis</u> <u>Salix petiolaris</u> <u>Fraxinus pennsylvanica</u> <u>Cornus obliqua</u> <u>Cornus stolonifera</u> <u>Acer saccharinum</u> <u>Cephalanthus occidentalis</u>

Adapted from: Bracken, R., and R. Huizer. "Lower Sucker Creek Wetland Evaluation." Ottawa: Atkinson and Huizer Biosurveys, 1994.

**APPENDICES # 2: DOMINANT PLANT SPECIES FOUND IN THE MARSHES,
SHRUB SWAMPS, AND TREE SWAMPS OF BIG MARSH AND THE STUDY WETLANDS**

B) Shrub Communities

- 1) **Black willow (Salix nigra)**: This is a shade intolerant pioneer species that grows on low ground along streams, river banks, flood plains and in swamps. It possesses adventitious roots that allow it to grow in early successional environments that are characterized by fluctuating water and sediment levels (Donovan et al., 1988).
- 2) **Peach-leaved willow (Salix amygdaloides)**: This species grows in low damp ground, along river banks, lakeshores, in alluvial woods, and along the margins of swamps and marshes (Soper and Heimberger, 1982).
- 3) **Meadowsweet (Spiraea latifolia)**: Meadowsweet grows in sandy or rocky soil, usually in moist situations near river banks, the edges of bogs, and on open low ground (Soper and Heimberger, 1982).
- 4) **Slender willow (Salix petiolaris)**: This species is chiefly found on low damp or wet habitats, along the edges of ponds, swamps, rivers, and lakes, in meadows, ditches, and ravines (Soper and Heimberger, 1982).
- 5) **Narrow-leaved meadowsweet (Spiraea alba)**: This shrub grows primarily in low moist fields, sedge meadows, swamps, roadside ditches, and along the shores of lakes, streams, and ponds (Soper and Heimberger, 1982).
- 6) **Broad-leaved meadowsweet (Spiraea latifolia)**: Broad-leaved meadowsweet grows on sandy or rocky situations that are usually moist. It can be found along river banks, the edges of bogs and thickets, in roadside ditches, and open low ground (Soper and Heimberger, 1982).
- 7) **Grey dogwood (Cornus racemosa)**: This shrub grows in thickets, and moist soil along river banks, roadsides, and fence rows (Soper and Heimberger, 1982).

- 7) **Grey dogwood (Cornus racemosa)**: This shrub grows in thickets, and moist soil along river banks, roadsides, and fence rows (Soper and Heimberger, 1982).
- 8) **Red ash (Fraxinus pennsylvanica)**: This tree typically grows on riverbanks and lakeshores (Hosie, 1990).
- 9) **White elm (Ulmus americana)**: White elm is common in wet sites and alluvial flats, where water often lies in the spring; however, it grows best on rich, moist sandy or gravelly loams and where the water table is close to the surface and there is good drainage (Hosie, 1990).
- 10) **Buttonbush (Cephalanthus occidentalis)**: This species is usually found in damp habitats, where its roots are waterlogged for at least part of the season (Soper and Heimberger, 1982).
- 11) **Silky dogwood (Cornus obliqua)**: This plant grows on low damp ground along streams and in marshes, ditches, thickets, and in open woods (Soper and Heimberger, 1982).
- 12) **Silver maple (Acer saccharinum)**: Silver maple trees grow best on rich, moist bottomlands along streams and the shores of lakes (Hosie, 1990).

C) Tree Swamps

- 1) **Black ash (Fraxinus nigra)**: This tree species is typically found in swampy woodlands (Hosie, 1990).
- 2) **Black willow (Salix nigra)**: This is a shade intolerant pioneer species that grows on low ground along streams, river banks, flood plains and in swamps. It possesses adventitious roots that allow it to grow in early successional environments that are characterized by fluctuating water and sediment levels (Donovan et al., 1988).

- 3) **Beaked willow (Salix bebbiana)**: This shrub grows in moist wet habitats that include sedge meadows, swamps, bogs, lakeshores, deciduous and coniferous forests and on limestone flats (Soper and Heimberger, 1982).
- 4) **Peach-leaved willow (Salix amygdaloides)**: This species grows in low damp ground, along river banks, lakeshores, in alluvial woods, and along the margins of swamps and marshes (Soper and Heimberger, 1982).
- 5) **Meadowsweet (Spiraea latifolia)**: Meadowsweet grows in sandy or rocky soil, usually in moist situations near river banks, the edges of bogs, and on open low ground (Soper and Heimberger, 1982).
- 6) **Red maple (Acer rubrum)**: This tree prefers moist soils along the borders of swamps; however, it may be found on upland soils (Hosie, 1990).
- 7) **Silver maple (Acer saccharinum)**: Silver maple trees grow best on rich, moist bottomlands along streams and the shores of lakes (Hosie, 1990).
- 8) **Common buckthorn (Rhamnus cathartica)**: This shrub grows in dry and moist habitats such as open pastures, fencerows, roadsides, clearings, and also in woods (Soper and Heimberger, 1982).
- 9) **Red osier dogwood (Cornus stolonifera)**: Red osier grows on low damp ground, along shores, river flats, the edges of marshes, in damp open woods, in thickets, and along roadsides (Soper and Heimberger, 1982).
- 10) **Trembling aspen (Populus tremuloides)**: This tree grows on almost all soils; however, it grows best on well-drained, moist, sandy, or gravelly loams (Hosie, 1990).
- 11) **Red ash (Fraxinus pennsylvanica)**: This tree typically grows on riverbanks and lakeshores (Hosie, 1990).

- 12) **Grey dogwood (Cornus racemosa)**: This shrub grows in thickets, and moist soil along river banks, roadsides, and fence rows (Soper and Heimberger, 1982).
- 13) **Narrow-leaved meadowsweet (Spiraea alba)**: This shrub grows primarily in low moist fields, sedge meadows, swamps, roadside ditches, and along the shores of lakes, streams, and ponds (Soper and Heimberger, 1982).
- 14) **Silky dogwood (Cornus obliqua)**: This plant grows on low damp ground along streams and in marshes, ditches, thickets, and in open woods (Soper and Heimberger, 1982).
- 15) **Slender willow (Salix petiolaris)**: This species is chiefly found on low damp or wet habitats, along the edges of ponds, swamps, rivers, and lakes, in meadows, ditches, and ravines (Soper and Heimberger, 1982).
- 16) **Crack willow (Salix fragilis)**: This shrub species grows in low areas along streams, rivers, edges of lakes and roadsides (Soper and Heimberger, 1982).
- 17) **Buttonbush (Cephalanthus occidentalis)**: This species is usually found in damp habitats, where its roots are waterlogged for at least part of the season (Soper and Heimberger, 1982).
- 18) **Weeping Willow (Salix babylonica)**: This is an exotic species that originated from Asia. It can grow on roadsides and on stream banks (Soper and Heimburger, 1982).

Appendix 3: Historic Water Levels in Lake Ontario

The original information for these tables has been obtained from a hydrograph that is found in Great Lakes Water Levels (Lloyd and Yee, 1989).

A) Minimum and Maximum Water Levels for Study Years

a) Water Levels For 1920-1929 (in metres):

Year	1920	1921	1922	1923	1924
Minimum	74.3	74.2	74.1	74.1	74.0
Maximum	74.6	74.9	74.9	74.6	74.7

Year	1925	1926	1927	1928	1929
Minimum	74.0	74.3	74.3	74.5	74.7
Maximum	74.5	74.4	74.7	74.9	75.3

b) Water Levels for 1953-1962 (in metres):

Year	1953	1954	1955	1956	1957
Minimum	74.7	74.7	74.7	74.5	74.0
Maximum	75.1	75.1	75.3	75.1	74.6

Year	1958	1959	1960	1961	1962
Minimum	74.0	74.1	74.3	74.2	74.4
Maximum	74.4	74.7	74.9	74.8	74.7

c) Water Levels for 1969-1978 (in Metres):

Year	1969	1970	1971	1972	1973
Minimum	74.3	74.2	74.3	74.5	75.4
Maximum	74.8	74.7	74.8	75.1	74.5

Year	1974	1975	1976	1977	1978
Minimum	74.3	74.4	74.5	74.3	74.2
Maximum	75.3	74.9	75.4	74.6	75.1

d) Water Levels for 1984-1993 (in Metres):

Year	1984	1985	1986	1987	1988
Minimum	74.3	74.3	74.9	74.3	74.3
Maximum	75.1	74.9	75.1	74.9	74.7

Year	1989	1990	1991	1992	1993
Minimum	74.3	74.5	74.4	74.4	74.4
Maximum	75.2	75.1	75.3	75.1	75.7

B) Annual Mean Water Levels (Metres)

a) Mean Water Levels for 1920-1929 (Metres):

1920: 74.6	1921: 74.7	1922: 74.7	1923: 74.5	1924: 74.6
1925: 74.5	1926: 74.5	1927: 74.7	1928: 74.9	1929: 75.2

b) Mean Water Levels for 1953-1962 (Metres):

1953: 75.1	1954: 75.0	1955: 75.2	1956: 74.9	1957: 74.6
1958: 74.5	1959: 74.5	1960: 74.7	1961: 74.6	1962: 74.7

c) Mean Water Levels for 1969-1978 (Metres):

1969: 74.8	1970: 74.7	1971: 74.7	1972: 74.9	1973: 75.2
1974: 75.1	1975: 74.8	1976: 75.1	1977: 74.8	1978: 74.9

d) Mean Water Levels for 1984-1993:

1984: 74.9	1985: 74.9	1986: 75.1	1987: 74.8	1988: 74.7
1989: 74.8	1990: 74.8	1991: 74.9	1992: 74.8	1993: 75.1

Appendix # 4: Seechi Disk Values Taken From Middle
Bay: Bay of Quinte (Measurements are taken in Metres)

1972 = 1.4	1973 = 1.2	1974 = 1.1	1975 = 1.0
1976 = 1.1	1977 = 1.3	1978 = 1.3	1979 = 1.3
1980 = 1.3	1981 = 1.4	1982 = 1.3	1983 = 1.6
1984 = 1.1	1985 = 1.2	1986 = 1.7	1987 = 1.7

Source: Bay of Quinte R.A.P: Preliminary Notes. unpublished,
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